The AMSAT® Journal

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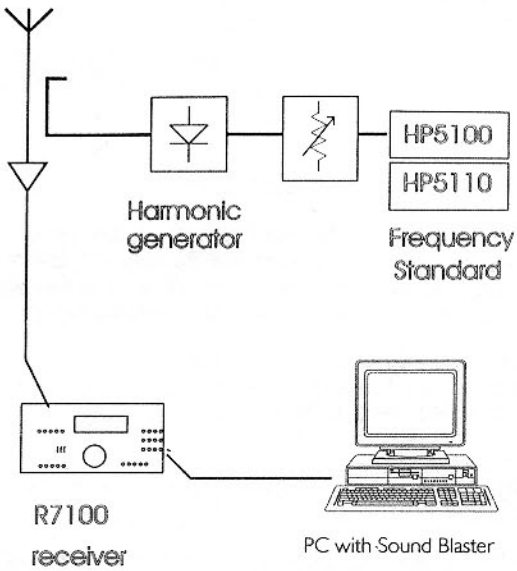

Figure 1. The basic receiving setup used at AA7FV for the MGS Mars Relay test. The antenna is a single 15x15 element crossed Yagi, phased for RHCP and steered manually. The receiver is an unmodified ICOM R7100, set to USB mode, with an antenna preamp. The expected signal frequency, after allowing for Doppler shift, is approximately 437.095 MHz. A weak but very stable local reference signal, set to a frequency about 300 Hz lower than that expected from the MR signal, was loosely coupled to the antenna. The receiver audio output was digitized at 5 kHz by a standard Sound Blaster card. Software running in the PC allowed measurements of the frequency and phase of the reference signal within the receiver passband ten times per second, to derive the frequency and phase corrections to be applied to the entire passband.

Receiving the Mars Global Surveyor Relay Using Phase Referencing for High Frequency Resolution

or

How to Use milliHertz Bandwidths with a Drifting Receiver

Darrel Emerson, AA7FV, G3SYS (*aa7fv@amsat.org*)

On 7 November 1996 the Mars Global Surveyor (MGS) was successfully launched on a journey to Mars, which it is expected to reach in September 1997. The communication to Earth from the spacecraft is carried out at X and Ka-band (experimental), but the Mars Relay (MR) on board transmits to the probes on the Martian surface at a **[continued on page 4]**

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Apogee View

Let's Keep Our Eyes on the Ball!
by Bill Tynan W3XO

Perhaps some of you have been following the debate on the Internet AMSAT bulletin board relative to projects AMSAT should pursue once Phase 3D is safely in orbit. Indeed, some have even hinted that we should abandon Phase 3D altogether, and strike out in some new direction; presumably one that would produce simpler, cheaper spacecraft more useful for average amateurs. One posting even contended that Phase 3D is aimed only at the high tech ham with a "30 foot dish in his yard!"

I think that anyone who has been following the development of Phase 3D knows that, from its inception, its design has been based on making satellite operation available to more amateurs than previous amateur satellites. However, that does not mean that it can defy the laws of physics, anymore than can any of these schemes promising systems of amateur satellites that can be accessed by any ham with an HT, and do it much more cheaply than Phase 3D. One individual, promoting one such scheme has even been claiming to have the backing of a major university and has already been actively soliciting funds presumably to build spacecraft - despite the fact that almost no engineering work has been accomplished to indicate that the concept might be even remotely feasible. Others have posted messages asking if there are *easy and cheap ways out.*

For instance, they wonder if small amateur spacecraft can be launched by amateur rocketeers? Cooler heads have responded with the facts of life. They point out that no amateur rocket has ever come even remotely close to achieving orbital altitude and velocity and there is no prospect that one will, in the foreseeable future. Press reports tell of a group in Australia which is doing more in this area than any others I have heard about. But, I have seen TV news clips showing at least one of their spectacular failures. When, and if, amateur rockets ever achieve the altitude and velocity necessary to orbit the Earth, it is unlikely that they will offer a viable means of putting up satellites that would be of much use to the amateur radio community. Since the rocket would have to be very small, so would the satellites. Also, the orbits would have to be very low. Very small satellites present significant limitations. They generally offer a short life and/or minimal communications capability. The Microsats, are small, but larger than some of the spacecraft being promoted; and probably larger than spacecraft that could be launched by an amateur rocket. Their success stems from the fact that they were designed primarily for one purpose, store and forward digital communication. The exception is Webersat, WO-18 which was designed for taking pictures. Even DOVE is a store and forward type of satellite in that it was designed to store uploaded digital messages and reproduce them as voice. Eye-Sat, or AO-27 as we hams call it, in addition to its experimental non-amateur store and forward application, does have the capability of relaying amateur FM voice transmissions in real time, but only on a single channel. In addition, the satellite's power budget is such that it can be operated in that mode for only a very small portion of its orbit. Very small satellites simply do not have much room for solar cells and hence do not generate much power. And, very low orbits are short lived and offer extremely limited communication range.

There is simply no way to get around the laws of physics. One can be innovative and try to make them work to advantage, but, there is no way of simply ignoring them.

But, some may ask: What harm is there in dreaming about these simple, cheap approaches? Isn't imagination the impetus for further research, study and development? Yes it is, but concepts arising from imagination must be tempered with realism and basic engineering analysis before being proffered as valid projects. To merely offer dreams as viable solutions to complex engineering problems is unproductive. Its principal danger is that of confusing people, and possibly convincing them that there is *an easy way out* - thus possibly diverting them from the task at hand. For example, if our members should become convinced that AMSAT has deliberately embarked on an expensive and complicated spacecraft design, intended only for the elite among us, simply because that approach appeals to its techie designers; support for this important project could be seriously eroded. As I have already said, the design features incorporated in Phase 3D are all aimed at making satellite operation easier, not more difficult. Why then, some might ask, does it include all of these higher frequency bands? Why not simply Mode B (Configuration U/V)? For the very good reason that satellite operation on the lower bands is becoming more and more imperiled as time passes, because of increasing amateur terrestrial use of the bands as well as their increasing non-amateur use. For example, just recently, the Guatemalan government announced that all amateur assignments between 148 MHz and 47 GHz are being deleted in that country, and the freed-up spectrum will be sold to commercial interests. This means that we may soon hear taxicabs and delivery trucks coming through our satellites including Phase 3D when it is in Configuration U/V and in view of Central America! In addition to this growing problem of QRM to amateur satellite operation in the 2-meter and 70-cm bands, I believe that it will become apparent, as time passes, that the higher bands offer much improved signal quality than the lower bands ever can. And, it may turn out that operation on the higher band is actually simpler than is our current Mode B. The antennas will be smaller, and less power will be needed for an adequate uplink

signal. In addition, the equipment already in our shacks does not have to be junked in favor of new expensive and exotic gear. The Mode B and Mode J satellite stations we have already, form the basis for our microwave satellite stations. The right place for both transmitting upconverters and receiving downconverters, is out at the antenna, not in the shack. In principal, merely connecting our existing 2 meter and 70 cm equipment to little antenna- mounted boxes will provide us with our satellite microwave stations. Suitable upconverters and downconverters are already available, and it is certain that additional, and less expensive, units will be marketed once Phase 3D is in orbit. Converting to the microwaves for satellite operation may well turn out to be easier and cheaper than getting on Mode B in the first place, or maybe setting up our terrestrial packet stations. In the meantime, Phase 3D will have Configurations U/V and V/U (Modes B and J), which we can use as we transition to the higher bands over a period, of perhaps, several years.

I believe that the harm done by those promoting these *easy* schemes, which have not been subjected to the scrutiny of engineering analysis, is that they carry the potential of diverting some people from the real task ahead of us - completing and launching Phase 3D. Until this is done, it remains AMSAT's sole satellite building effort. The promise of an *easy-way-out* has never led to satisfactory results. Even if a viable alternative were to present itself, it would not be wise to abandon all we have accomplished and start in some new direction. Trying first this, and then that, without finishing anything, is an unfortunate habit many of us share. But, it's an approach that never accomplishes anything. Sure, some thought is being given to what AMSAT might do following completion and launch of Phase 3D, but I assure you that none of that musing is having an effect on completing the task at hand. Some concepts for possible future satellites have even been set down on paper. You will see one idea that has occurred to me in the next issue of *The AMSAT Journal*. But, the AMSAT Board has not endorsed my approach, or any post-Phase 3D concept as yet. And, I am not out attempting to raise money to start building, it or anything other than Phase 3D. Unfortunately, the same cannot be said for some proponents of supposedly simple and easy amateur satellites.

Let's keep our eyes on the ball! ■

[Mars Relay, Continued from page 1]

frequency of 437.1 MHz. Nearly three weeks into its trip, when at a distance from Earth of 5 million km, the 437.1 MHz transmitter of the MR was turned on. The transmitter power was only 1.3 watts, into a near isotropic antenna. For several hours on November 25-26 the MR transmitted a steady unmodulated carrier, and Radio Amateurs around the world were invited to try to detect the weak signal.

In preparation for the test, an Internet e-mail reflector was set up. In the months leading up to the test there was some fascinating correspondence, involving complete antenna designs, discussion on DSP techniques and general issues regarding the reception of weak signals, and details of how to track the MGS. A World Wide Web page devoted to the test was prepared at JPL (Reference 1). The Web page included a table prepared by Dr. John Callas of NASA Jet Propulsion Laboratory (JPL) indicating that, with a 21.5 dBi gain antenna, and with low receiver noise, the signal would be detectable with just a few dB of signal-to-noise ratio (s/n) if a bandwidth of 1 Hz could be used. With amateur-scale antennas, this signal would never be heard as such; some type of digital signal processing would be required to detect and display the signal.

Even though just the simple detection of a single weak carrier was involved, many amateurs were prepared to go to an enormous amount of effort, including the design and construction of special antennas, in preparation for the event. During the test itself, the Internet was used heavily for participants to report their success (or failure) in receiving the signal, and for the control station at the SRI International/Stanford University 150-ft dish to give updates on the status of the MR. At Stanford a special Mars Relay Flight Test Home Page was set up, making available the latest spectra received on the Stanford 150-ft dish, and even a TV image of the control room, updated in near real time (Reference 6).

A description of the project, by Michael Owen and John Callas, appeared in QST in January 1996 (Reference 2). The minutes of a meeting held at JPL in June, 1996 specifically on the Mars Relay Flight Test were written by John Callas and published in *The AMSAT Journal* (Reference 3). A summary of the results of the MR test is expected to appear in *QST* later this year.

Preparations at AA7FV

At AA7FV, space for antennas is severely limited. The best 70-cm antenna available is a single 15x15-element crossed Yagi, phased for RHCP, and with a gain of about 16.5 dBic. The JPL analysis suggests this is not good enough. The system noise temperature is estimated at 150 K, but most of that comes from antenna sidelobes seeing the ground, with some sky radiation from the direction of the MGS; the receiver noise (antenna preamp NF 0.4 dB) is a relatively small contribution. The best hope of detecting the signal seemed to try to achieve a bandwidth much narrower than 1 Hz. This would be obtained by digitizing the receiver output, and using digital signal processing (DSP) in a PC to give high resolution spectra of the digitized data. Roughly speaking, a Fourier transform of t seconds of data will result in a frequency channel bandwidth of (1/t) Hz. If repeated spectra are obtained, sensitivity can be built up by averaging successive observations - for a given frequency resolution, s/n improves as the square root of the number of spectra averaged, or in other words as the square root of time. However, for a given total observing time, better sensitivity is achieved by averaging fewer, but higher resolution, spectra - the s/n improves as $1/\sqrt{}$(bandwidth), for a given total observing time.

There is a limit to how far the bandwidth can usefully be reduced. Since I wanted to be able to measure the strength of the MR carrier as often as about once every 100 seconds, this limits the potential frequency resolution to about 0.01 Hz. However, the receiver to be used for the test, an Icom R7100, can drift in frequency by tens of Hz in 100 seconds, so hopes of achieving 0.01 Hz bandwidth at first appeared to be slim. I am not aware of any receiver available to the amateur that has adequate frequency stability with sufficiently low phase noise; a frequency resolution of 0.01 Hz at 437 MHz corresponds to a fractional stability of 2 parts in 10^{11}. Data from JPL suggested that the instability of the MR transmitter itself would be enough to smear out the signal much more than this, making even 0.1 Hz DSP bandwidth of questionable value. Finally, a combination of changing Doppler frequency shift caused the MGS motion with respect to the Earth, and the relative motion between my own location and the MGS caused by the Earth's rotation, would

cause a steady change in received frequency of up to nearly 0.04 Hz/second - the precise value depending on the latitude of the observer and the celestial coordinates of the MGS. Even ignoring transmitter and receiver instabilities, in the 100 seconds required to obtain 0.01 Hz resolution, the received signal frequency may change by as much as 4 Hz.

I hoped that these factors could be overcome. The Doppler shift, and rate of change of Doppler shift, should be calculable given the data from JPL on motion of the MGS, and in principle DSP algorithms can be made to track the changing frequency. There was clearly nothing to be done about instabilities in the MR transmitter itself, other than to hope that the JPL estimates were overly pessimistic. To cancel out my receiver drift, I used a stable reference signal loosely coupled to the antenna to measure, and then correct, the receiver frequency and phase drifts.

Correcting for Receiver Drifts

The R7100 receiver has internally 4 separate frequency conversion stages, each with its own independent local oscillator, not all crystal controlled, and all of which contribute to the overall phase and frequency instability. The receiver would be used in SSB mode, giving a baseband audio signal to be digitized by the PC Sound Blaster card. Even drifts of the clock controlling sample rate in the Sound Blaster can introduce unwanted phase drifts into the signal path; I required the phase, not just frequency, to be stable through the receiver for 100 seconds. Ideally, all of these independent oscillators, and the Sound Blaster sampling, would be phase locked to some high precision frequency standard, but this was just not feasible.

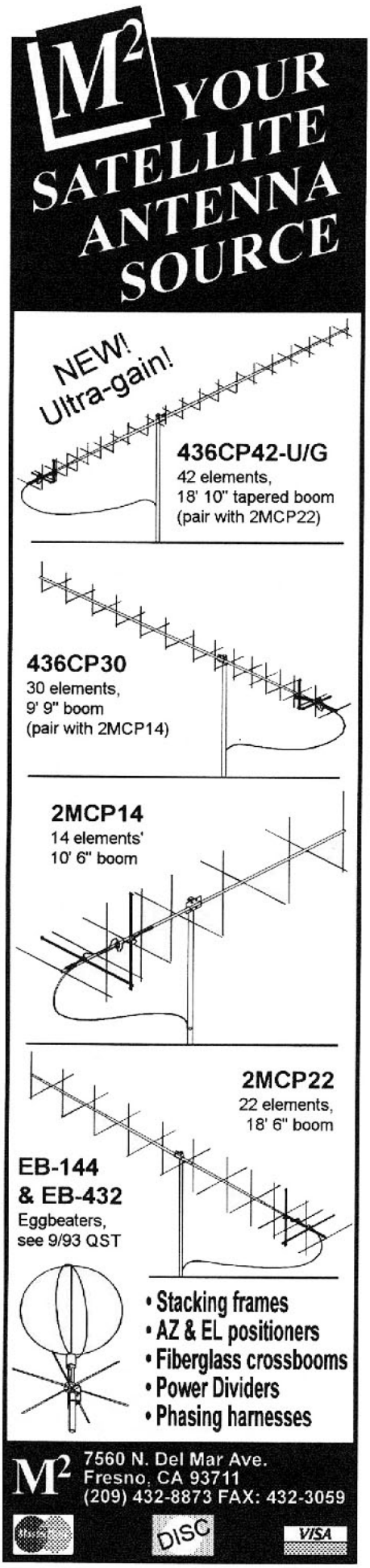
Rather than trying to control the phase and frequency of all the local oscillators and the digitizer, I elected instead just to try to measure the overall frequency and phase drift, which could then be corrected in software before a Fourier transform (FFT) analysis. This would also allow a fairly simple correction for predicted phase changes from the changing Doppler shift caused by the changing relative motion of my antenna, as the Earth rotates and the MGS moves in its own orbit around the Sun. To be able to measure the drifts, I would inject a locally generated, stable signal into the receiver, which would then be subject to the same frequency and phase shifts as the wanted signal. I could measure the total frequency and phase drift in this reference signal, and use the results to correct the entire digitized receiver passband. Figure 1 shows the basic arrangement. The frequency standard is a 30-year-old HP 5100/5110 combination, obtained at a local hamfest, driving a simple diode harmonic generator to produce a detectable signal at 437 MHz..

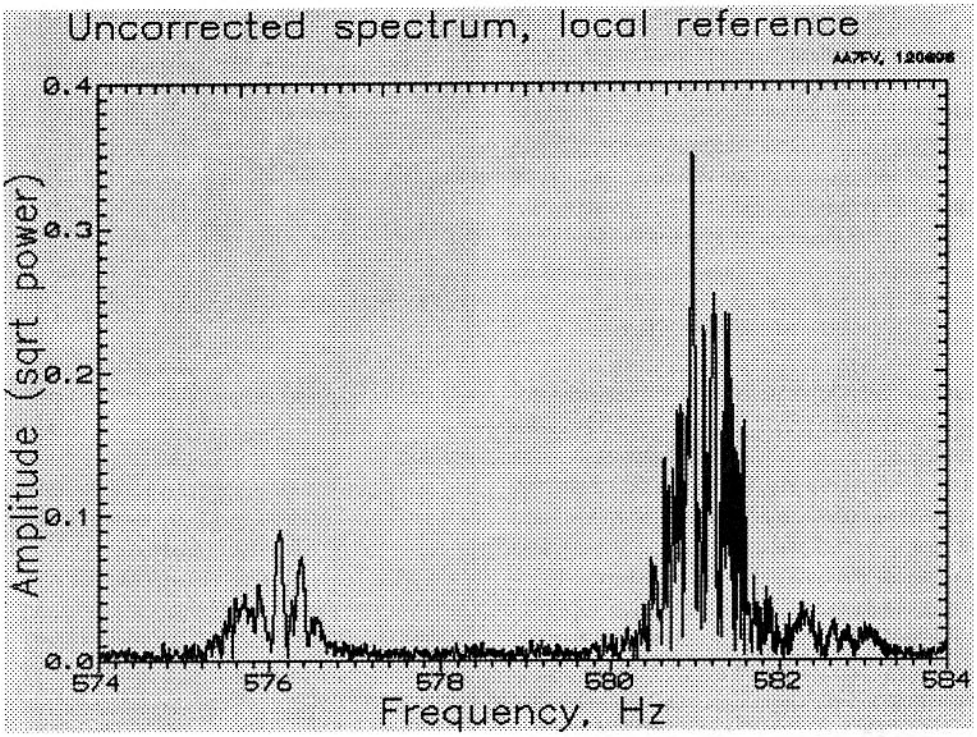
Details of the Algorithm

For each measurement set, the signal was digitized by the Sound Blaster at 5000 8-bit samples per second, for 105 seconds. The data analysis for each 105-second measurement proceeded in 2 phases:

1) Each 0.1 seconds of data (actually 0.1024 s) was analyzed with an FFT to give approximately 10 Hz resolution, covering the receiver i.f. bandwidth of about 2.5 kHz. With this resolution, the reference tone was located in the computed spectrum, and its precise frequency and phase measured. These measurements were compared with the predicted frequency and phase of the reference at the time of the 0.1-second sub-sample, had there been no drifts. One assumption here is that the drift within the 0.1-second sub-sample is small enough to be insignificant in the corresponding 10-Hz bandwidth; even for my receiver, that is not unreasonable. Frequency drifts and phase noise measured on the reference signal will apply equally to all signals in the receiver passband. The difference between prediction and measurement on the local reference was then applied to the entire spectrum. At this stage additional frequency and phase offsets were applied to the 0.1-second sub-sample of data, based on the predicted change of Doppler shift of the received signal, so that the changing MR signal would then appear in the corrected data as a signal stationary in frequency and phase. Since frequency is the rate of change of phase, a constant rate of change of frequency becomes a quadratic term in phase; for a steady frequency drift rate (df/dt) the resultant phase change at elapsed time t, to be applied to the entire spectrum, is $\pi(df/dt)t^2$.

After all these corrections to the 10-Hz resolution frequency spectrum, the inverse FFT of the spectrum was computed, overwriting the raw data samples from the corresponding 0.1 seconds of raw data, with the corrected data. This entire process was re-





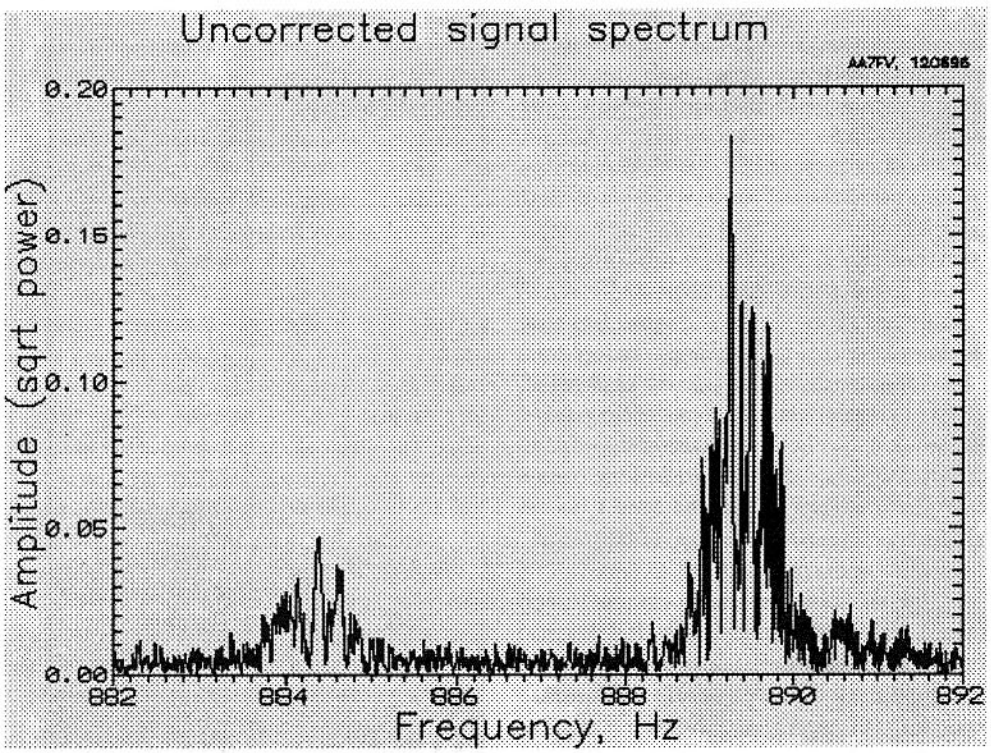


Figure 2a (above) and Figure 2b (below). In advance of the Mars Relay test, the phase referencing scheme was tested using the stable carriers of the time data transmissions from the geostationary satellites GOES-9 and GOES-8, on 468.825 and 468.8375 MHz. The spectra show the signal received from the local reference (a) and from GOES-9 (b), using 105 seconds of data, but without applying the phase referencing technique. Without receiver drifts, the frequency resolution would have been 0.013 Hz, but because of receiver drifts the energy from both the local reference and from the GOES-9 transmission is diluted over many Hz of the receiver passband.

peated for each of the 1024 0.1-second subsamples in the complete 105-second data set.

2) I then computed a single, large FFT for the entire 105-second dataset. If step 1) has worked, and if the reference tone is sufficiently stable, then the MR signal in the corrected dataset should be phase stable for the 105-second duration, allowing the full frequency resolution of 0.01 Hz to be obtained. After weighting to reduce the frequency sidelobes in the output spectrum, the DSP filter bandwidth between -3 dB points is 0.013 Hz.

Far from being an annoyance, the known frequency drift rate of the received signal helps considerably; in fact is almost essential in separating the true MR signal from terrestrial interference. The frequency drift can be regarded as a natural form of spread spectrum modulation. The software analysis rejects all signals except those with the correct modulation, or drift rate.

The choice of 0.1 seconds for how often to measure and correct sub-samples of these data was based on the worst-case receiver stability. This assumes that the receiver is stable enough for 0.1 second duration that any signal will remain well within one 10-Hz resolution element of the small FFT, and that adequate s/n on the measurement of the phase of the reference within 0.1 seconds is achieved. The technique effectively corrects for all phase noise on the receiver local oscillator chain within the 10-Hz bandwidth.

The level of the injected reference signal is a little critical, within about 10 dB. If it is too strong, then the receiver and sampler may become non-linear, and combined with the frequency sidelobes of the strong reference signal after the FFT, spurious signals may be generated which could mask the real wanted signal. If it is too weak, it may be difficult to measure its phase with sufficient precision for an adequate correction of the receiver drift.

Computationally, the sequence outlined above is extremely inefficient. However, the approach is conceptually fairly straightforward, which certainly helped in the software implementation and debugging stages.

Tests of the Algorithm

The technique clearly needed to be tried out well in advance of the MR test. An inde-

pendent, stable signal source is needed to test both the software algorithms, and the stability of the local phase reference. The geostationary weather satellites GOES-8 and GOES-9 send telemetry giving precise time information on 468.8375 and 468.825 MHz (reference 4). The carriers of these telemetry signals turn out to be extremely stable, and ideal test signals.

Figure 2(a) shows an uncorrected spectrum of the audio from the receiver tuned to a harmonic, at 468.824700 MHz, of my local frequency standard; this is just a 10-Hz section of the 2.5 kHz band available after a simple FFT of the data samples, but with a potential frequency resolution of 0.013 Hz. The receiver was set to USB mode, and I recorded 105 seconds of data with the Sound Blaster sampling the receiver audio at 5 kHz. This locally generated signal is set to be 300 Hz below the carrier of the GOES-9 signal; both are within the receiver passband. Figure 2(b) shows a similar spectrum, from the same 105 seconds of data, of the carrier of GOES-9 on 468.825 MHz. A simple ground-plane antenna was used, fed to the receiver through 50 ft. of lossy coax, without any antenna preamp. I have not yet applied any frequency or phase drift corrections. Although the potential frequency resolution is 0.013 Hz, because of receiver instability the energy both from the local reference signal and from the GOES-9 carrier has been spread over several Hz. In both (a) and (b) there is a main peak, 1 or 2 Hz wide, with a secondary broad peak in energy about 5 Hz lower, which presumably results from a receiver frequency jump of that amount during the data recording. The encouraging factor is that the broad spectrum on the GOES-9 signal looks almost identical to that of the local reference signal.

Figure 3 (a) and (b) show the same data, but now analyzed using the locally generated signal as a phase reference, exactly as outlined above. As expected the spectrum of the reference shown in Figure 3(a) now has the theoretical spread between -3 dB points of only 0.013 Hz, confirming that the frequency spreading shown in Figure 2 came from phase and frequency instability, without any significant amplitude noise. In Figure 3(b) the narrow GOES-9 carrier is now very clear, with frequency width very close to the same theoretical value of 0.013 Hz. This shows that the phase and frequency drifts and jumps measured on the local reference signal are essentially identical to those on the GOES-9

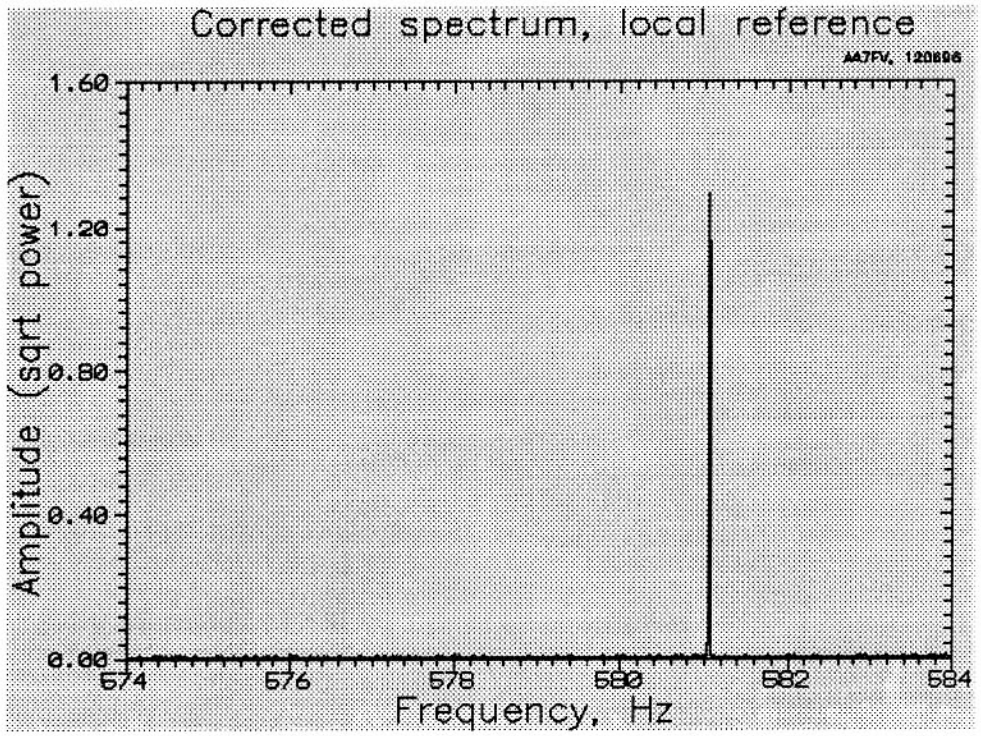
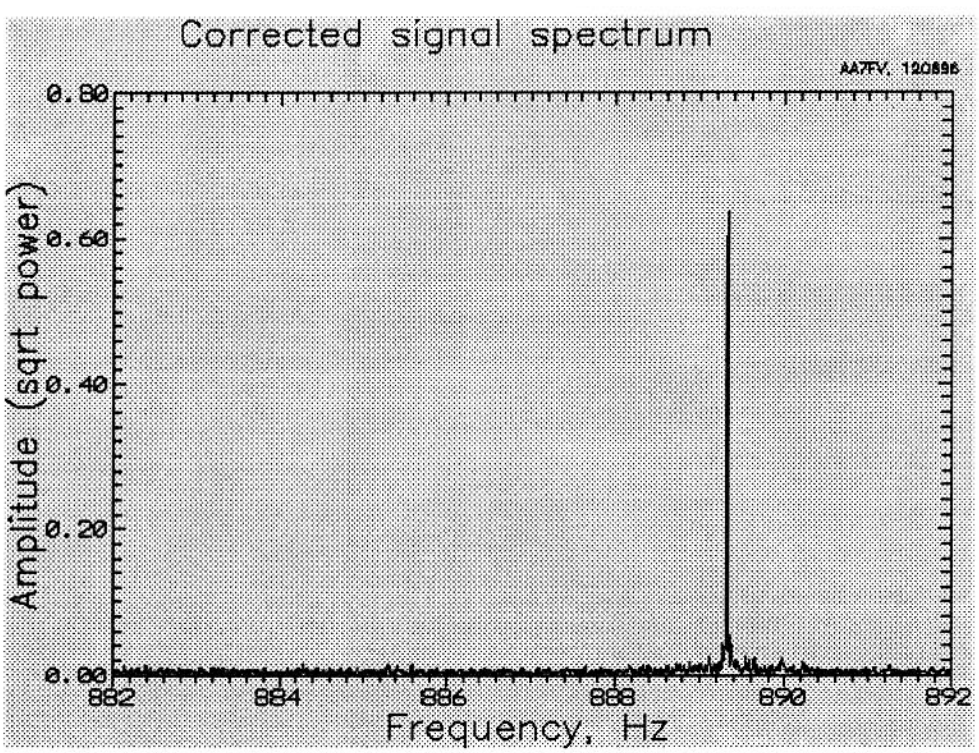


Figure 3a (above) and Figure 3b (below). This shows the same 105 seconds of data as displayed in Figure 2, but applying the phase referencing scheme to correct for receiver drifts, and assuming a zero frequency drift rate on the 468.825 MHz transmitted signal. As expected, energy from the local reference signal is now confined to within the theoretical bandwidth of 0.013 Hz, but this is also true for the GOES-9 signal. The phase referencing has been completely successful. The measured width (-3 dB) of the GOES-9 signal is now only 0.0132 Hz, essentially equal to the theoretical value.



carrier. The instabilities arise entirely within the receiver and affect both signals in the same way. The frequency and phase corrections, based on measured receiver instabilities using the local reference signal, have allowed the DSP to give an almost perfect correction of the GOES-9 signal. Close inspection of Figure 3(b) reveals a slightly higher noise base within one Hz of the signal, but this noise is about 30 dB or more down on the signal. The technique appears to be almost 100 percent effective.

Tests of Frequency Stability of the Local Reference

Although the software algorithm seemed to work, it does rely on adequate stability of the reference signal. Because my test (Figure 3) measures a near-theoretical signal bandwidth, I know already that the reference signal is sufficiently stable over 100 seconds. I would like to check its longer term stability as well.

Figure 4 shows the measured offset of the GOES-9 carrier signal from my local reference, with the phase-referencing drift compensation algorithm in effect, over a five-day period. My local phase reference signal was ·300 Hz below the GOES-9 carrier nominally at 468.825 MHz. There is an obvious near-sinusoidal variation, with a period of 24 hours, and a peak-to-peak amplitude of a little more than 1 Hz. My frequency reference had been left turned on for several weeks to allow thermal stabilization as far as possible, but I believe the daily frequency drifts result mainly from the daily temperature variation inside the room containing my frequency reference; the orbital motion of GOES-9 may also contribute. The maximum rate of change of frequency is about 1 Hz in 10 hours, or 0.00003 Hz/sec. This will cause negligible smearing in the 100 seconds needed to obtain 0.01 Hz frequency resolution, as already shown in Figure 3.

This was much better than I had anticipated. Even slight deviations in the nominally geostationary orbit might have generated +/- a few Hz of Doppler shift on the GOES-9 signal over 24 hours. I repeated the measurements on the sister satellite GOES-8, which has a corresponding transmission on 468.8375 Hz. The results were the same - a near sinusoidal variation in frequency with a 24-hour period, of amplitude similar to the easurements on GOES-9. Unless both the GOES-8 and GOES-9 satellites have frequency drifts or orbital motions that exactly cancel the drifts of my own frequency reference, the conclusion is that my local frequency standard can be relied on to within about +/-0.7 Hz over a 24-hour period. This is certainly adequate for the MR test.

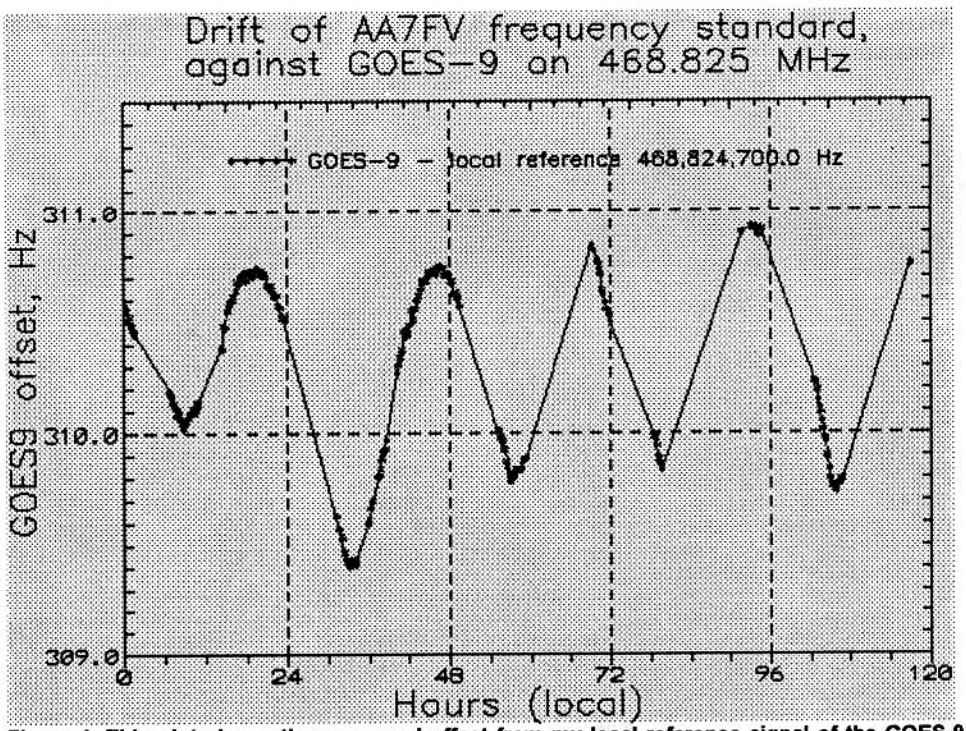


Figure 4. This plot shows the measured offset from my local reference signal of the GOES-9 telemetry carrier on 468.825 MHz. My reference was set to 468.824700 MHz, 300 Hz lower than the nominal GOES-9 frequency. Data are shown for a 5-day period. The daily variation is only about +/-0.5 Hz, and almost certainly results from changes in ambient temperature around my standard oscillator, although orbital motion of the nominally geostationary satellite may also contribute. The maximum rate of change in the frequency difference, ignoring any instability of the GOES-9 transmission, is only 0.00003 Hz/second. This is much better frequency stability than that of the MR 437.1 MHz transmitter.

Although my frequency standard is apparently very stable, its absolute frequency may not be correct. Frequency drifts could have meant the complete failure of the experiment. Small frequency offsets are of relatively little consequence, other than increasing the range of frequency which will have to be searched for signal. Nevertheless, I did my best to align the frequency standard to the WWV standard frequency transmission. By choosing times when the ionosphere appeared to be stable, with some care I was able to align my standard to give consistently less than one cycle per 20 to 30 seconds in difference frequency from WWV at 5 MHz. (A convenient technique is to offset the local reference by 1 Hz with respect to WWV, and then to listen to the 1 Hz beat note superposed on the 1-second time ticks from WWV. A gradual drift in phase of the 1 Hz beat with respect to the 1-second ticks is easy to hear.) The accuracy is fundamentally limited by small Doppler shifts on WWV introduced by changes in height of the reflecting region of the ionosphere. A GPS-based frequency standard such as the TAC developed by Tom Clark, W3IWI (Reference 5) would have been much easier and more accurate.

After this alignment the accuracy of my standard should then be 1 part in 10^8, or about +/-5 Hz at 437 MHz. With respect to my standard, I measure the GOES-9 signal to be on average approximately 10 Hz higher than its nominal 468.825 MHz, but I find the GOES-8 signal within 1 Hz of the advertised 468.8375 MHz.

Alternative Stable Phase-reference Sources

I had been particularly lucky to obtain the HP5110 stable oscillator at a local hamfest. However, the demands on stability for the phase referencing signal, although certainly not trivial, may not be quite as hard to achieve as seems at first sight. The stability of the reference frequency is critical, not so much its absolute frequency. Even if the reference frequency drifts, provided the drift rate is constant, or at least reproducible, it can be allowed for in data analysis. The design and construction of a stable frequency standard

probably comes down to providing a sufficiently stable thermal environment. The performance of a homebrew frequency reference oscillator can easily be checked against a stable transmission such as the GOES-8 or GOES-9 468 MHz carriers.

Frequency standards are available which are locked to one of the standard frequency transmissions, such as WWVB at 60 kHz. With the availability now of cheap GPS receivers, there is further potential for a much higher precision frequency standard. Tom Clark, W3IWI is exploiting this concept in the context of his Totally Accurate Clock (TAC) - see reference 5. However, although the TAC gives literally atomic long term (hours to weeks) stability, on time scales of a few minutes or less, any frequency standard based on a standard GPS receiver still has to rely on the stability of its own internal crystal oscillator. The GPS-derived frequency standard will still require a very high quality internal crystal oscillator if it is to support coherent integrations of 100 seconds or so, needed to obtain 0.01 Hz frequency resolution. The GPS-derived standard will however always be very much more accurate in its absolute frequency, which indirectly helps sensitivity. With a frequency resolution of 0.01 Hz, if the frequency uncertainty is only 1 Hz, there are 100 frequency points to search. With the same frequency resolution of 0.01 Hz, if it is necessary to search as much as 200 Hz of bandwidth because of frequency uncertainties, there are 20,000 frequency points to consider. With 100 possible frequency points, applying a threshold of about 3.7 times the RMS noise gives a probability of only one percent of random noise falsely being interpreted as true signal. With 20,000 points, to ensure less than one percent probability of random noise giving a false detection, you have to apply a threshold of 4.7 times the rms noise in the same resolution bandwidth. If a large range of spectrum has to be searched, this is equivalent to an extra loss of detection sensitivity. (The precise factors depend on the detailed statistics of the noise, and will vary according to specifics of the receiver and DSP systems.)

There is no requirement for complete frequency synthesis from the local phase reference. A simple harmonic generator - such as a rectifying diode driven from a frequency divider circuit - should be adequate. I just used a diode directly across the generator output. For example, a 1 MHz crystal oscillator could be divided down to 2 kHz. Some

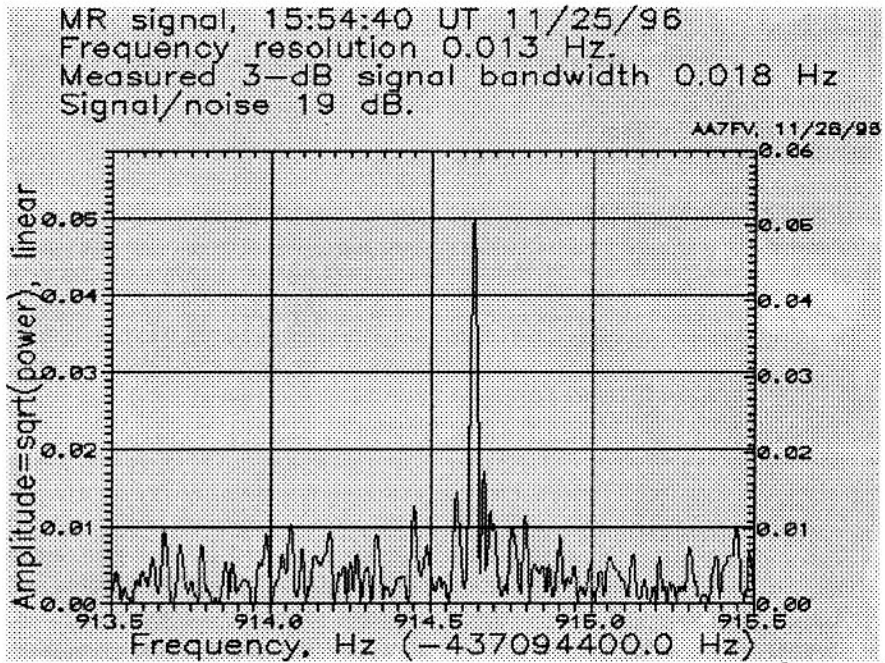


Figure 5. This is a spectrum showing the absolute amplitude (proportional to √power) of the signal received at AA7FV from the MR transmitter, over a 2-Hz range of frequency. The DSP filter resolution is 0.013 Hz, and the measured width of the received signal is 0.018 Hz. To produce this spectrum 105 seconds of data from 15:54:40 UTC, digitized at 5 kHz, were analyzed - 524288 or 2^{19} samples. I used an assumed frequency drift rate of 0.02 Hz/second in the analysis, rather than the 0.037 Hz/s expected then from the changing Doppler shift of the MR, based on its motion with respect to my antenna. I believe the discrepancy comes from a slow frequency drift of the MR transmitter, perhaps caused by internal temperature changes. Note that the frequency drift rate assumed in the analysis is a fairly critical parameter. During the 105 seconds of data used to generate this spectrum, the received frequency changed by more than 2 Hz. Drifts of the R7100 receiver in this time, but measured and corrected for using the injected stable reference tone, were several times greater than this.

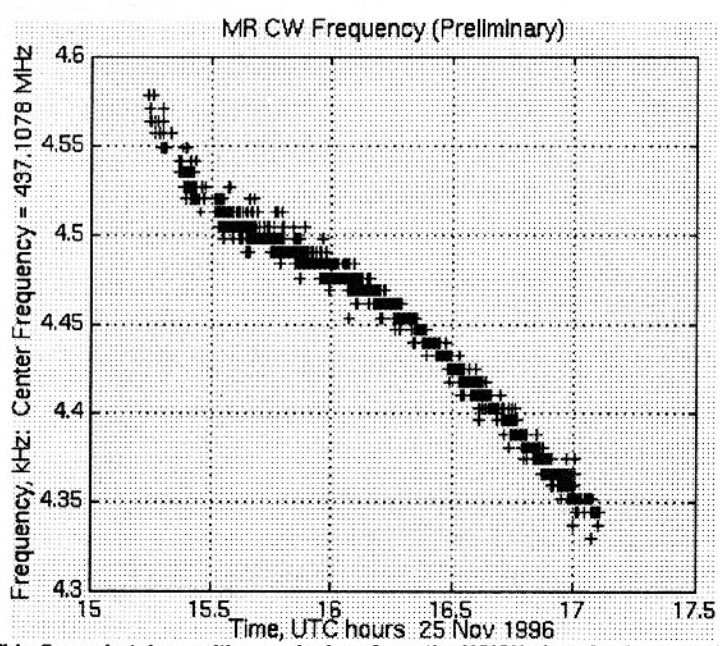


Figure 6. This figure is taken, with permission, from the WWW site of reference (6), where the caption includes: *The MR beacon frequency is plotted versus time above. The frequency of the peak signal in each of our spectra is indicated with a '+'. ... The frequency changes smoothly with time due primarily to Doppler shifts caused by the Earth's rotation. This figure was obtained using our low-volume archive of threshold data and should be considered preliminary. Our frequency resolution for the processing of the MR beacon signal was approximately 7.5 Hz.* The overall trend, frequency decreasing at about 0.037 Hz/s, is consistent with the Earth's rotation. Just before 16 hours UTC the rate of change of frequency has decreased significantly, to only a little over 0.02 Hz/s. The same decrease is found in my own data (Figure 7), and I believe indicates a true frequency drift of the MR transmitter.

harmonic of the 2 kHz signal is guaranteed to be within 1 kHz of any signal, and could be used as the phase reference. The main receiver is then only required to have sufficiently accurate calibration to identify which 2 kHz reference harmonic is which, and only needs to be sufficiently stable that the reference harmonic and wanted signal stay within its (say) 3 kHz passband.

Results on the Mars Relay Transmission

The initial attempts to receive the MR transmission were a little disappointing. At a time when the predicted rate of change of Doppler shift at my QTH was -0.037 Hz/sec, I could not at first find evidence of any signal with my 0.013 Hz resolution. However, after smoothing the power spectra to a frequency resolution of a few tenths of a Hz, I started seeing the MR signal, although close to my noise threshold. My preliminary conclusion was that JPL had been correct; higher resolution than 0.1 Hz did not appear to be usable with the MR transmitter.

After following the MR spectra for several minutes, using frequency resolutions of 0.1 to 0.5 Hz, I noticed that the rate of change of received frequency was only about half that predicted at the time for my location. As a test, I recomputed the spectra using a drift rate of only -0.02 Hz/s, rather than the predicted -0.037 Hz/s at that time. Somewhat to my astonishment, the MR signal then came booming through, with a measured signal-to-noise ratio of 19 dB. The measured 3-dB width is 0.018 Hz, showing only slight broadening compared to the instrumental resolution of 0.013 Hz. This MR spectrum is shown in Figure 5. The integrated MR signal in this spectrum is 2.7 dB lower than I had anticipated, based on the best estimate of my receiver noise and antenna gain, assuming for the MR a 1.3 watt transmitter into an isotropic antenna at a distance of 5.026 million km. The slight discrepancy probably results mainly from an underestimation of my system noise temperature or perhaps variations from isotrophic in the MR antenna pattern.

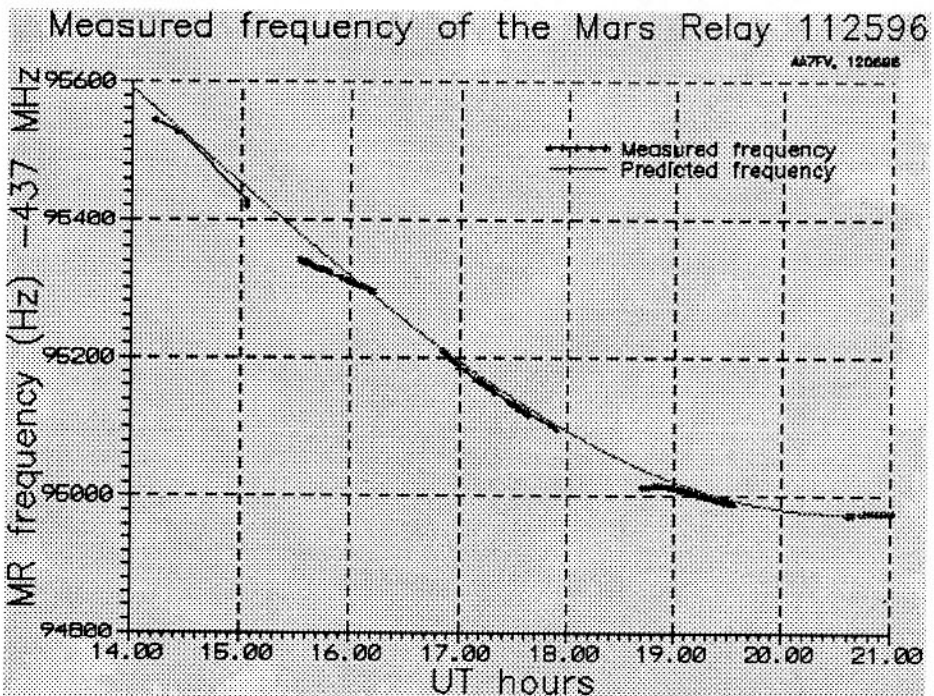


Figure 7. This figure shows my own measured frequencies of the MR transmission, with the continuous line showing the predicted MR frequency at AA7FV assuming a transmitted frequency of precisely 437.1 MHz. Each point represents 105 seconds, or 524288 data samples. The precise frequencies were derived from a least-squares fit of a Gaussian curve to the strongest peak found in the spectrum. There are periods when I did not record any data, such as between 14:26 and 15:03 UTC. The signal strength of the MR transmission varied as the pointing of the transmitter antenna changed, with the 100-minute period of spacecraft rotation. At minima of the MR antenna polar diagram, the signal goes below my threshold of detection. The steady frequency drift of the received MR signal, resulting mostly from the Earth's rotation, is very clear. The measured and predicted frequencies agree to within a few Hz for most of the time, although there are some obvious periods where the measured rate of change of frequency differs significantly from the prediction. The peak difference in frequency is about 40 Hz, which could be the result of a 6 degree C change in temperature of the MR.

While this first successful spectrum was being computed on my PC, a new image (Figure 6) appeared on the Internet at the Stanford University Mars Relay Flight Test web site (Reference 6), plotting the measured frequency for the MR signal received at the 150-ft dish between 15:00 and 17:30 UTC on 25 November 1996. Most of the frequency change shown results from the changing projected velocity of the Stanford site as it rotates with the earth, but from 15:30 to 16:00 UTC the rate of change is seen to be much less than at other times - i.e. much less than predicted. This confirmed perfectly my own measurements of the received frequency drift. The anomaly presumably comes from instability of the MR transmitter, caused perhaps by heating of the space probe.

So, the conclusion is that the original JPL specifications for instability of the MR transmission are close to the truth, but that the dominant form of the MR transmitter instability is a long-term frequency drift. By allowing for the MR drift rate, added to the known Doppler shift from relative motions of the MR and the receive antenna, most of the energy from the MR transmission can be confined within 0.02 Hz. For a given observing time, compared say to averaging many spectra taken with 2 Hz resolution, this is a 10 dB gain in sensitivity - enough to make up for my too-small antenna.

Figure 7 shows the frequency of the MR measured at AA7FV from 14:00 UTC until 21:00 UTC, compared to the predictions based on Doppler shifts due to its relative motion. The measurements near 16:00 UTC are in excellent agreement with the Stanford data shown in Figure 6. Gaps in the measured data occur when the antenna of the MR was pointing away from the Earth, and match the 100-minute rotation period of the MR. The measured frequencies match the prediction quite well, although there are occasional deviations of up to 40 Hz. This could result from heating of the MR, caused perhaps by its rotation in sunlight. From data provided from JPL, a 40 Hz frequency shift corresponds to about 6 degrees C change in temperature of the MR transmitter.

At least from my perspective, the experiment has been a success.

Limits to Useful Frequency Resolution

There has already been discussion on the Internet as to whether it may be possible to

detect the same 1.3-watt transmission from the MR when it is in orbit around Mars. When it is nearest to the Earth, Mars may still be 80 million km distant. Compared to the 5 million km of this MR test, that represents a signal 24 dB weaker.

The sensitivity to a narrow-band signal increases as $\sqrt{(T/B)}$, where T is the total observing time and B the bandwidth. Keeping the resolution at 0.01 Hz, averaging 100 spectra could in principle increase the sensitivity by 10 dB, although nearly 3 hours would then be required for one such observation. Decreasing the resolution bandwidth from 0.01 Hz to 0.001 Hz, spending 1000 seconds of coherent integration rather than 100 seconds, could also in principle increase the sensitivity by 10 dB. Corresponding precision in frequency, and in knowledge of the orbital motion of the MR, would of course be needed. The stability of the local phase reference signal sets the limit at the receiving station; drifts of the receiver itself are of almost no consequence.

The measurements in this test already show some slight spectral broadening of the MR signal, so a frequency resolution of 0.01 Hz is probably about the limit of what is useful for the MR. If the MR transmitter had been locked to the atomic standard on board the spacecraft (the Radio Science Ultrastable Oscillator to be used for some scientific experiments at Mars: see reference 1), then perhaps milliHertz resolution would have been usable. The MR transmitter is the limitation here, rather than my own frequency reference.

Apart from the stability of the transmitter and receiver oscillators, and knowledge of dynamics of the spacecraft so that Doppler rates can be calculated with the necessary precision, there are other factors which limit the usable frequency resolution. The ionosphere introduces phase fluctuations at frequencies of a few hundred MHz, equivalent to broadening the bandwidth of the received signal; the magnitude of the effect rises in proportion to wavelength, is worse during day than at night, and is 5-10 times worse at solar maximum than at solar minimum (Reference 7). Above about 2 GHz, fluctuations in the troposphere become more important than ionospheric instability, with any broadening of signal then being proportional to frequency.

Radio astronomical observations made using very long baseline interferometry give a direct measurement of the phase noise introduced by the ionosphere (Reference 7). At a frequency of 430 MHz, given sufficiently stable reference frequencies, a frequency resolution of 0.01 Hz should nearly always be possible without significant degradation, but the ionosphere may prevent higher resolution from being useful for much of the time. At 144 MHz the situation would be three times worse. It may be possible at some level to model the ionosphere, using published data on the total electron content (TEC) along the line of sight, and including this factor in DSP algorithms, but this has not been tried.

The conclusion is that, although 0.01 Hz may not quite be the narrowest useful bandwidth, I probably cannot expect to gain an extra 10 dB in s/n just by narrowing my resolution bandwidth much further - even ignoring instabilities of my reference oscillator and of the MR transmitter. Sensitivity can be improved further by post-detection averaging, but with very much longer total observing times. A larger antenna would help!

Summary & Acknowledgments

By using a highly stable reference tone injected into the receiver passband, the combined frequency and phase drifts of the receiver local oscillators can be measured, and, provided the wanted signal remains within the basic receiver passband, the drifts can be canceled by suitable software. Using DSP, 105-second coherent integrations on the MGS Mars Relay transmitter have been achieved, giving a frequency resolution at 437.1 MHz of 13 milliHertz. Without use of the stable reference tone, receiver drifts would have limited the useful DSP bandwidth to several Hz. The result of phase referencing is an increase in s/n of more than 10 dB, for the same observing time. Changes in Doppler shift during the integration period, caused by the motion of the MGS and the Earth's rotation, have to be taken into account, but given good predictions of the satellite dynamics, this is relatively easy to do. The changing Doppler drift rate is in effect a form of spread spectrum modulation, and provides a very useful, perhaps essential, tool for rejecting terrestrial interference.

Although even narrower bandwidth could increase sensitivity much faster than post-detection averaging, the stability of the MR transmitter probably limits usable bandwidth to a little more than 0.01 Hz. Even ignoring instabilities at the transmitter and receiver, at 430 MHz the passage of the signal through the earth's ionosphere may prevent frequency resolution much better than 0.01 Hz from being useful for much of the time.

I would like to thank the Dr. John Callas, with the staff at JPL and at Stanford, for making the Mars Relay test open to Radio Amateurs, and for providing support over the Internet before and during the test. I also thank Dr. John Callas for helpful comments on the manuscript.

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(3) "Minutes of the Mars Relay Flight Test Workshop" by Dr. John Callas, JPL. *The AMSAT Journal*, Vol 9, No.4, July/August 1996, pp.29-31.

(4) "GOES Satellite Time Service." Information available from: *http://www-bldrdoc.gov/timefreq/service/goes.htm*

(5) Tom Clark, W3IWI/TAPR TAC-2 (Totally Accurate Clock) Project, December 1996. On the WWW at *http://www.tapr.org/tapr/html/tac2.html*. See also relevant files at *ftp://aleph.gsfc.nasa.gov/GPS/totally.accurate.clock.*

(6) See the "Stanford University Mars Relay Flight Test Home Page" on the WWW, at *http://nova.stanford.edu/projects/relay/*. There is a link from there to several related pages, including the frequency drift plot, "MR CW Power and Frequency," at *http://nova.stanford.edu/projects/relay/mr-cw.html.* These web pages were prepared by Joe Twicken at Stanford University.

(7) "VLBI Phase-Referencing," by A.J. Beasley and J.E. Conway, Chapter 17 in Very Long Baseline Interferometry and the VLBA, ASP Converence Series, Vol. 82, 1995. Eds. J.A. Zensus, P.J. Diamond and P.J. Napier, published by the Astronomical Society of the Pacific. ■

Phase 5A Kick-off Meeting

Translated from *The AMSAT-DL Journal*

by John Bubbers, W1GYD

Editor's Note: While in Germany on Phase 3D business, Dick Jansson, WD4FAB and Keith Baker, KB1SF attended this meeting. Their summary of this meeting was provided in the September/October issue of The AMSAT Journal. Currently, Phase 5A is shaping up to be primarily a German funded project.

At the invitation of Dr. Karl Meinzer, DJ4ZC of AMSAT-DL and the Central Electronic Development Laboratory at Marburg University and Professor Dr. Ernst Messerchmid, DG2KM from the Institute for Space Travel Systems at Stuttgart University, the first official meeting took place on July 18th and 19th, 1996 to discuss a possible follow-up mission to the AMSAT Phase 3D international communications and experimental satellite.

An interplanetary follow-up mission to the anticipated launch of the Phase 3D satellite for the first half of 1997 has been discussed for a period of time.

A mechanical structure was developed for AMSAT Phase 3D which could supply a Delta-V driving force equal to 2.4 km/sec. This velocity makes it possible to reach Mars and achieve an orbital path around the red planet. During the kick-off meeting for such a mission, interested parties were to assemble and discuss the mission's initial goals. To that end, nearly 40 participants met at Marburg University, Marburg, Germany.

The President of Phillips-Marburg University, Professor Schaal opened the meeting and greeted participants. In his opening speech, he referred to the problems of ambitious space travel projects and to the lack of general acceptance of such missions. He expressed the hope for the Phase 5A project that, among other possibilities, more cost-effective space travel would be demonstrated.

Dr. Karl Meinzer, head of AMSAT-DL and current Phase 3D project director, then greeted those guests present on behalf of AMSAT-DL. He opened the meeting with a presentation of AMSAT and the Phase 3D mission to the guests from various universities, scientific institutions, and space travel agencies, who have had no previous contact with AMSAT. He further introduced the previous feasibility study results of a Mars mission and possible orbital scenario for the launch window of April 16, 2001.

After a comprehensive overview of those Mars missions planned by other space agencies by the year 2005, he touched upon the first part of the presentation concerning orbital questions and various propulsion possibilities.

Additionally, the availability of solar energy and thermal environment of a Mars orbit were commented upon. Accordingly, the solar energy is only half as great as on Earth. Given the premise, that a space vehicle of the planned dimensions consumes approximately 300 Watts of energy, this would permit a target temperature of 10C degrees.

The second part of the first day was filled with presentations and initial discussions on communications between Earth and the space vehicle. Under optimum conditions, it would be possible to have radio contact using a 3-meter parabolic reflector antenna. With this scenario, an S-band uplink and an X-band downlink were envisioned.

Under these prerequisites, it would not be possible for a Radio Amateur with average antenna facilities to participate. It would nevertheless, be possible for the amateur radio community to be included in this project for example via packet radio network or the Internet community participants and with connections of individual gateway stations.

The primary assignment for a Phase 5A satellite, for example, might be data transfer between the Mars land vehicles, which NASA has planned for the succeeding ten years, and Earth. The land vehicles would require only one link to the Mars orbiter, not one all the way back to Earth.

The RUDAK technologies developed for Phase 3D would have the advantage in comparison to other Mars orbiter schemes, since nearly all conceivable modulation modes and transfer protocols have been flexibly configured and thus the procedures of the variously planned land vehicles could be accommodated.

The second day was occupied with the realm of scientific payloads. Previous Mars missions were not able to answer all of the questions posed, instead they brought up more questions. Accordingly, a Phase 5A mission, aside from the relay station function, would be of interest as a carrier of scientific instruments.

Several short presentations, camera systems, magnetic and optical sensors as well as spectrographic analyzers were introduced.

Several of the experiments would require a different Mars orbital path from the one offered by Phase 5A, or they might need to be placed on the Martian surface. To accomplish this, proposals were also made for small land probes and off-loadable pico satellites.

After several assignments for future investigations were distributed, Professor Messerchmid summarized the meeting with the charge, the with the means and methods developed by AMSAT, that a low cost Mars mission would be possible, one which would not follow the maxim *keep it simple stupid*, but rather would be *better, faster, cheaper*. A future meeting was planned for the last quarter of 1996.

As a result of a press conference held during the lunch break on the second day of the Kick-off Meeting, there were featured items on the regional and national television news as well as on the science pages of numerous daily newspapers. ■

The LA2QAA Special
An Indoor 2m/70cm J-Pole Antenna

John A. Hackett, LA2QAA, AMSAT-UK 5868
Packet: *LA2QAA @ LA6K.KSU.T.NOR.EU*

Living on a somewhat remote Norwegian Island ensures I have plenty of *space* to experiment with antennas. My thoughts often turn to the high rise apartment dwellers who are not so fortunate. I decided to see if I could develop an effective indoor aerial for the mode-J user. The dual 2m/70cm J-pole seemed to be a likely candidate as its main advantages being: that it requires no radials, has a low vertical radation angle and requires minimum *space*.

Tests with a pair of RHCP and LHCP Lindenblads have shown that for angles below about 60 degrees the J-Pole is more effective. For angles over 60 degrees some form of turnstile array is more desirable. Studies of FO-20 passes over/near my QTH using *InstantTrack* software have shown that 75 percent of the time the satellite is under 60 degrees elevation. So I settled on the J-pole.

Normally, on RX I use one or a pair of 13 element beams for the downlink mounted on azimuth/elevation rotators so it would be interesting to see how the signals fared using the proposed dual J-pole indoors.

After having constructed the *BSA* (*Bits Stuck Anywhere*) prototype and being pleasantly surprised at the results I constructed *Mark 1* as illustrated in the Diagrams 1 and 2. Hopefully the diagrams are completely self explanatory (anyone having problems can always ***scream*** at me via FO-20) and anyone possessing 2.5 meters of 13mm aluminum tubing and half a brain (more than I've got mate!) should be able to duplicate the antenna without experiencing major problems. I have made J-poles from 3mm copper wire and 5mm aluminum rods. Recently I mass produced a *series* for the mainland group members using everything from bent nails to the XYL's mainstays! All worked perfectly [at least they did at my QTH...at group members' QTH we had everything from:....."can't find the on/off switch"...to..."yes, but where's the accelerator"...(???)] The only thing I wondered about was *sticking* the die cast preamp box halfway up the pole! It should work though (thought I) after all, the 70cm part of the antenna is just a bit of top loading as far as the 2m part of the antenna is concerned. For once the theory worked out well in practice! The SWR at the points mentioned later were 1:1 for the 2m antenna and 1.2:1 for the 70cm antenna.

Obviously the RX signal could not compare to that received using the outdoor beam but it was respectable. I worked three regulars on one pass and they did not even realize I was using an indoor antenna. In fact, I received my first FO-29 QSL on 24 August 1996 using this antenna. A low noise GaAsFet preamp would improve the noise figure but the object of the exercise was an ***easily*** duplicated indoor antenna for the newcomer or those who suffer from antenna restrictions.

The J-pole is a halfwave radiator with a quarter wave matching stub. It is named because in its single mode configuration it resembles the letter J. (The fact that I designed this particular J-pole for *mode-J* is merely a coincidence).

I mounted my antenna on a 230mm diameter steel plate for stability. The main radiator fits nicely over a 100mm long by 10mm diameter threaded rod bolted through the baseplate. Rubber feet protect the XYL's floor from scratches. (If you're smart, you'll keep them happy...whatever the cost, you'll save yourself a lot of grief in the long run - hi.) The base is painted *matte* black to keep the SWR down. (Just joking folks, the real reason is that it looks *professional* with the *brushed aluminum* antenna.....steel wool and elbow grease!) All the *bits n' pieces* came out of the junkbox but even with brand new nuts n' bolts, etc. the total cost is still ***less*** than that of a 2m rubber duck antenna.

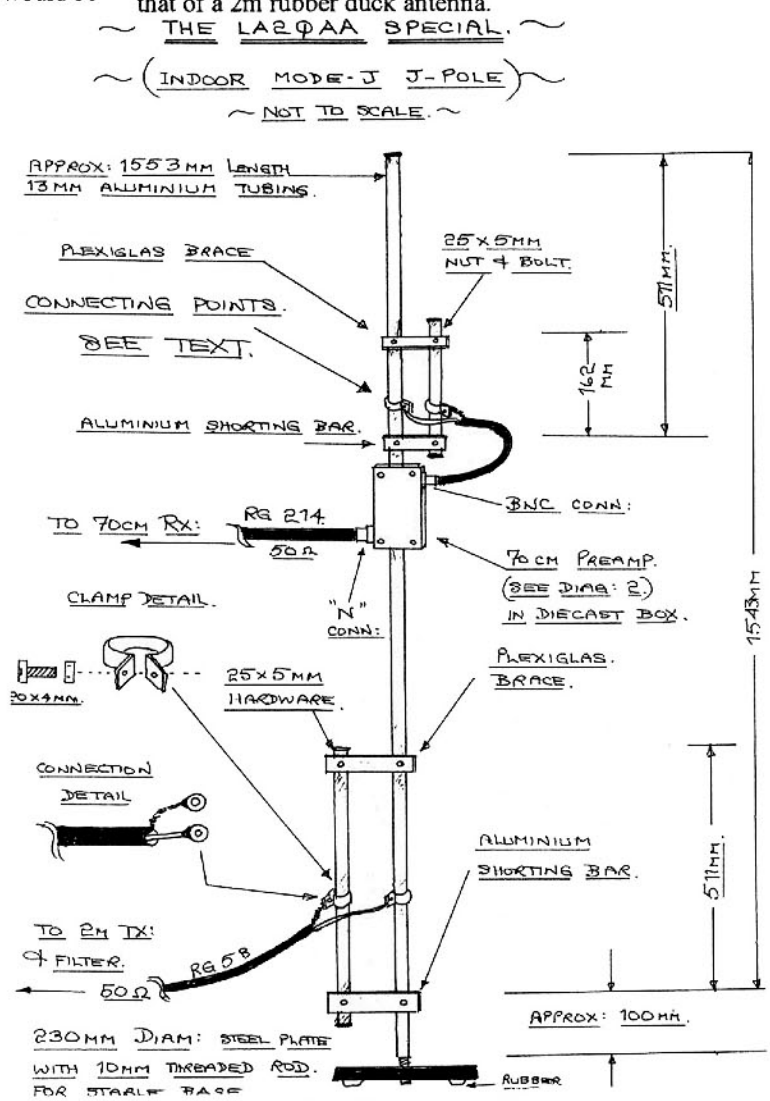

Diagram 1. The LA2QAA Special - Indoor Mode J J-pole Antenna.

I used an ancient TS-700G transmitter (5w) and a brand spanking new (I sold my soul....***again***!) TR-851E UHF transceiver for receiving. Though I had several successful QSO's I did suffer a slight *swishing* from the transmitter in the 70cm passband. A filter that is described in *OSCAR News* (Number 113, June 1995, page 6) will cure this if anyone finds it bothersome. [I have never experienced this problem with my outside antennas, but then again they are not mounted like everyone else's!...(hi hi)....(I refer to a previous *OSCAR News* article.)]

At present I am experimenting with parallel stripline filters and hope to make such a mode-J filter an integral part of the dual J-pole. (*Editor's note: see Postscript.*)

Mounting the die cast box immediately below the 70cm antenna posed no problem at all. At my QTH the connecting points are as follows:

- 70cm Antenna: Clamps fastened 56mm above the aluminum shorting bar.
- 2m Antenna: Clamps fastened 105mm above the aluminum shorting bar.

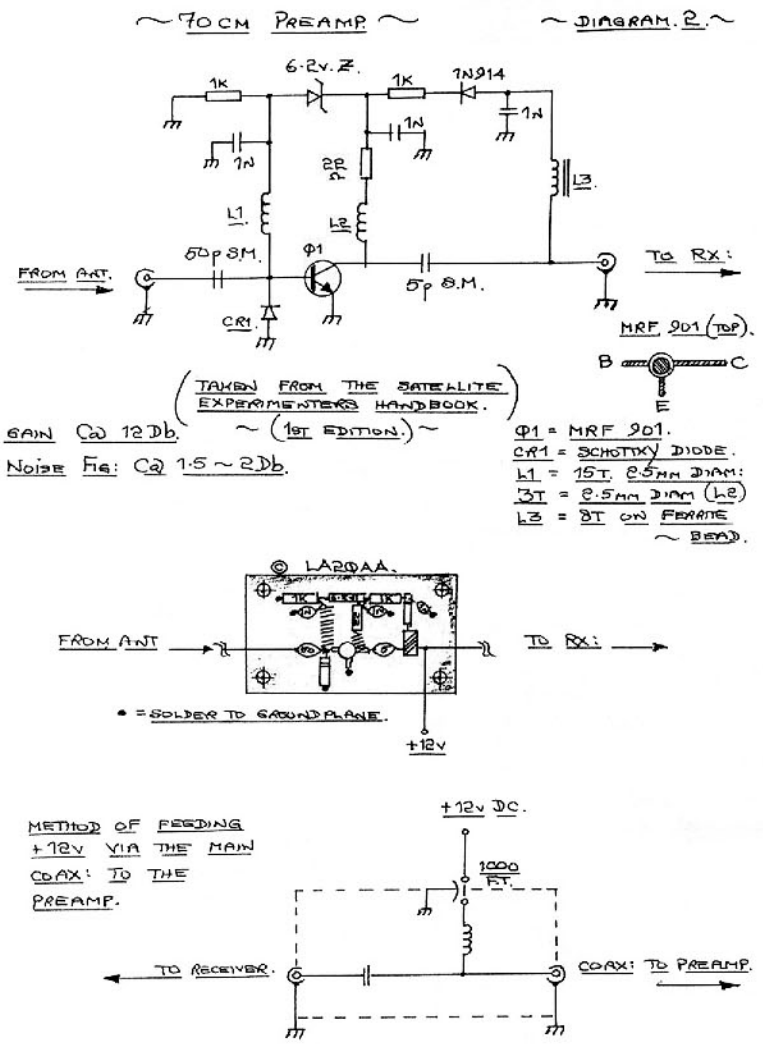

Diagram 2. 70 cm preamp (from *The Satellite Experimenter's Handbook*).

Adjust for a perfect match. Bending them towards or away from each other will *fine tune* the SWR. I have used black plastic end caps to give it that *professional* finish.

Those who claim they cannot work satellites due to antenna restrictions now have ***absolutely no excuse***! Criticisms to *The AMSAT Journal* staff, monies and praise to me!.

A Postscript
Observations from Norway

Editor's note: LA2QAA is a British expatriate living on Frei Island on the coast of Norway. From time-to-time, LA2QAA writes "Observations from Norway" for AMSAT-UK's OSCAR News. The following is provided for those who are not familiar with LA2QAA's unique style and enthusiasm. He asks that past issues (number and age not important) of The AMSAT Journal that are destined for the trash can be sent to him postage guaranteed at Bjerkaas Gaard, N-6420 Rensvik, Norway. Tusen takk!

Due to a severe snowstorm recently, *observations* have been limited to peering out of the shack window! AO-13 having ...(sensibly) *migrated* to the Pacific region....FO-20 being *as low as you can get*...(at my QTH) in the evenings...and Phase 3D twiddling its thumbs *over there*...there hasn't been too much to observe in an upward direction. Consequently, of late, I have had to fire-up the Morse key and reacquaint myself with the RS-series of satellites. One cannot be other than impressed at the way RS-10 goes on and on...etc....if Phase 3D performs to this standard we should all be well pleased...all credit to the RS design team.

Due to the extreme cold that inevitably follows great snowfalls up here...my elevation rotator froze solid!....(interesting to note...the *cheapo* TV azimuth rotator didn't)...therefore, to operate FO-29, the dual J-pole has been put into service....I built two preamps...so that I could compare them...one using a MGF1302 GaAsFET and the other a BFR34A bipolar transistor...(the BFR34A being *easy*....designed for the newcomer). I must now admit that I was a mite *optimistic* re: the BFR34A preamp...While it did perform!...it performed ***noisily***...in fact, the copy was better ***without*** the preamp!...(One has to delve into the realms of EME to fully appreciate the term *noise figure*....therefore....back to the drawing board and the MGF1302 replaced the BFR34A...the MGF1302 being *tuned* for the lowest noise component on the received signal. After trying several *experiments* to overcome the *easy way out* problem....using a *broadly* tuned bipolar on 70cms....I've come to the conclusion that (for once?) theory and practice agree! For acceptable performance in a noisy environment (read: high rise apartment in Manhattan!) one ***must*** use a low noise GaAsFET preamp. (I can't get away with a BFR34A because the noisiest thing within two miles of my QTH is the sound of a polar bear walking across the garden!)

So....unfortunately, the *newcomer* must either purchase a GaAsFET....or become *acquainted* with a soldering-iron-wielding Elmer prepared to *throw* a preamp together for him/her.

In the original J-pole article, I mentioned the *swishing* from the TX signal in the receiver passband and advised a mode-J filter. In Norway, commercial oil industry communications have been centered around 450 MHz but are now *going up* toward the microwave region. This means, providing you know a man who has a brother who knows a man etc....there is a surplus of equipment that would make any ham retailer rich! (Providing he could get his fingers on it.) Anyway, a while ago, I had a call from the person responsible for dumping the goodies, asking if I was interested in 150 meters of three inch coaxial cable and one or two other *bits n' pieces* which compromised a six foot parabolic reflector and feedhorn, a 40 meter length of two inch 75 ohm coaxial cable, a four foot parabolic reflector, a bag of N-type chassis connectors, four full wavelength cavity resonators for 450 MHz, 6x100 watt dummy loads for 500 MHz on enormous heat sinks, four microwave circulators and a solid brass dual cavity filter weighing at least ten pounds (this was *tunable* from 420 to 460 MHz so it was the perfect mate for my dual J-pole.) The original connectors were solid stainless steel heavy duty 28mm types...not having mating plugs I performed a little surgery and replaced them with standard N-type connectors and RG-214M cable which has a double silver coated braid and is only 2mm larger in diameter than RG213. An extra *bonus* on the filter...as well as having tuning screws both on the top and sides of each stack and the input and output connectors...it had a standard BNC type socket mounted in the end of the base...this suggested that the base was in fact a resonant cavity...removing 24 (!) screws revealed a copper stripline in the base...after a quick retune...with the filter connected to the rig and one of the dummy loads...5 watts at 435 MHz was *shoved* into the blunt end...a 600 MHz counter was connected to the BNC socket and sure enough, the meter showed 5mw at 435 MHz....

Obviously, not everyone can get their hands on a commercial doubly tuned cavity filter for 435 MHz. But with the help of hand tools and a bit of brass sheet, it is not that difficult to make one.

An aside....Russ Tillman, KC5JVB...(anyone not knowing Russ should be placed before a firing squad and shot!)...has relatives only 11 miles from my QTH so perhaps Frei Island is not quite as *remote* as it appears. (*Editor's note: Not really shot, perhaps just a mild beating. I do look forward to an eyeball QSO with LA2QAA while on family vacation in Norway this summer.*)

It is nice to hear Bob, G8ATE fairly regularly on FO-20. I am impressed with the signal when he is using his 8 element quad...I recall building an 8 element quad myself several years ago...gave a very potent signal on 2-meters.

Just lately I have noticed that FO-29's spin rate needs a few extra revs...perhaps someone could just nip outside and give it a push? I find I have to change polarization very frequently.

I started using the FODTRACK autotracking system (See May/June 1996 issue of *The AMSAT Journal)*...very easy, simple to construct and most importantly, ***cheap***. It works fine for azimuth and elevation and autotuning the TX/RX...or both...for normal or inverting transponders. FODTRACK is available on Internet. The downloaded files to disk include interface diagrams for the autotracker as well as for the optional tuner. Total cost for parts in Norway is about $30 (about half that in the US I would imagine). Compare that with KCT or Trackbox or AEA system...about two hours work....(including etching the PCB)...and you have a fully automated computer tracking of any satellite you care to enter Keplerian elements for in the set-up file. I have been waiting a long time for a program like this. The only *grouch* I have is that on a single computer....i.e. 286 without *Desqview*, it can only run in the foreground...that is to say...on my system. I cannot look at *InstantTrack's* maps at the same time! Consequently, I am attempting to get Instantrack running fully automated. I have obtained the necessary TSR's and I am just waiting for a circuit diagram from a 1987 edition of *QEX.*

More on *tuning* conventions...or...some do n' don'ts. It appears like RTTY on HF there are two conventions...American and European. What the *rest* do seems to change daily! John Brannegan, GM4IHJ (logically?) suggests that the ***receive*** (downlink) frequency remain *fixed* while the transmit (uplink) frequency is adjusted for Doppler. (This was particular to FO-20 mode J so would be the same convention as is respected internationally on mode B.)

Our American cousins however prefer fixed downlink with adjustable uplink for mode B but ***opposite*** for mode J....for the following reasons....the higher the frequency the more extreme the Doppler. Therefore it is *easier* to *tune* the ***higher*** frequency (i.e. on mode J tune the downlink).

One is *logical*, the other is *theoretically correct.*

What happens in the real world is that *some do* and *some don't*...which often leads to some stations waltzing across the passband and causing QRM to stations following the opposite convention. Now I am not going to stand on a soapbox and get hit by flack from opposite camps by *declaring* either one to be *correct.* What I will do however, is respectfully suggest via the editors of various AMSAT publications (*Editor's Note: Perhaps amsat-bb would be the place to discuss this topic?*) that we *get our act together* and agree on what convention is to be used by whom and when!...thereby avoiding the unnecessary QRM. We cannot do anything about the VFO swishers. Just remember, the object of this exercise is to irritate you....most newcomers become irritated...if you ignore them...they will go away...and be irritated themselves....after all, it is no fun trying to irritate someone who *won't bite.* ■

NOVA for DOS, Windows or **new Windows 95: $49.95. WinTrak Pro: $69.95. SASI Sat Tracker: $279.95. Freq. Mgr.** (radio auto-tune for Doppler shift): **$65.95. Mode S Downconverter** (Get ready for P3D now while prices are still low!): **$349.95. SB-32 Mode S 2'X3' Parabolic Dish** antenna for 2.4 GHz: **$55.95.** Yaesu **G-5400B** Az/El rotor: **$526.95.** Shipping extra on all. **Dealer** for all **M2, Eggbeater** and **KLM** antennas: Call for prices. *OSCAR Satellite Report* Newsletter: **$35** USA. Elsewhere higher. Special 8' Fiberglass boom, 1-1/2 inches solid: **$79.95.** HF antennas, too! Call/write/email/Web page.

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YAscan Satellite Signal Analysis

Andrew Cornwall, VE1COR

cornwaab@ednet.ns.ca

Last spring I began writing a several-line BASIC computer program to work with the Computer Assisted Tuning (CAT) capabilities of my Yaesu FT736R transceiver. I wanted to scan amateur VHF and UHF frequencies and record any instances of interference on the bands frequently used by amateur satellites. Starting as a simple project with very limited objectives, the task grew. The result is a program called YAscan. In developing this program I sought the assistance of 12 Internet correspondents on *amsat-bb*, who tested and commented on various and sometimes badly flawed early versions of the program. Al Lawler, WB1BQE and author of the program FT736l, was especially helpful and persevered until a stable, full-featured version YAscan was produced.

YAscan controls the receive frequency of the of the FT736R, and reports the S-meter reading of any signals encountered as a percentage of the meter's full scale (i.e. between 0 and 100). Scanning occurs across a selected range of frequencies or a set of specific frequencies, depending on how YAscan is configured. There are several options for saving output to disk files.

You can download freeware YASCAN18 from *http://www.ednet.ns.ca/~cornwaab*, and become familiar with its operation and features. The program is executable, has instructions built-in, and runs under DOS on most any PC.

This article, however, is not about YAscan the computer program. Rather I want to show how data collected using YAscan can be used to analyse amateur satellite ground station operation. My primary interest is in the 9.6K bps digital Microsats, and KO-23 in particular.

The first use of YAscan was to scan a range of Amateur Radio frequencies in the VHF and UHF bands to detect any local interference on the satellite sub-bands. Figure 1 shows the results of a one such scan of 800 frequencies covering 144 to 148 MHz in 5 kHz increments. The fastest scan rate is nearly four frequencies per second as determined by the ability of the FT736R to respond to commands to change frequency, check for open squelch, and retrieve the S-meter reading. As shown in Figure 1 the set of 800 frequencies was swept 64 times during three and one-half hours. In this period there were 162 instances, or hits, when a signal of some kind was encountered that exceeded the transceiver's squelch threshold. Amateur Radio enthusiasts who live in urban areas may be surprised by the low utilization of frequencies encountered in the VHF band. There was one relatively strong hit of 88 at 145.900 MHz, which is in the range of the frequencies used by a number of OSCARs; and a recurring (22 hits) low-level signal or noise of 4 to 6 on the meter at 145.540 MHz, a SAREX uplink frequency.

The remainder of this article deals with the analysis of data captured by YAscan during orbit number 20,042 of KO-23 on 16 November, 1996. This pass of KO-23 started at 17:21:28 UTC when the Microsat rose above the horizon from the direction of 200 degrees. KO-23 proceeded high across the sky to descend into the 35° horizon at 17:43:24 UTC. During the pass KO-23's elevation reached 88° which was a horizon-to-horizon pass of 1,316 seconds.

As the pass occurred, YAscan continually tuned the FT736R receiver across a set of 25 frequencies, in 1 kHz increments, from 435.163 MHz to 435.187 MHz, and recorded the respective signal strengths. This range of frequencies brackets KO-23's transmitter frequency of 435.175 to account for Doppler shift. It takes approximately eight seconds to sweep the set of 25 frequencies. In all, the range of frequencies was scanned 154 times during the pass, recording the signal strength of 1,481 *hits*. For these measurements the transceiver was set to USB mode to take advantage of its greater selectivity. In USB the recorded signal levels are reduced by about 30 percent compared to the FM mode, but this deviation does not distort the recording of relative signal levels.

SCAN: 144.000 MHz - 148.000 MHz Step: 5 KHz Mode: FMN Started: 16:19:32

SCAN RESULTS

Freq.	Hits	S-Meter.		Time Range	Freq.	Hits	S-Meter.		Time Range
144.910	1	100	100	19:11 19:11	147.210	9	17	23	16:38 19:03
144.950	2	99	99	18:24 19:44	147.270	2	99	99	16:59 17:36
144.970	5	13	99	16:37 19:44	147.330	7	72	75	17:59 19:46
145.030	9	71	99	16:20 18:31					
145.050	3	92	99	17:30 19:34					
145.055	1	88	88	19:28 19:28					
145.250	2	6	7	18:01 18:17					
145.540	22	4	6	16:24 19:35					
145.900	1	22	22	17:24 17:24					
146.250	5	10	13	18:18 18:35					
146.490	1	6	6	17:45 17:45					
146.500	5	31	33	16:58 17:48					
146.700	53	4	7	16:21 19:49					
146.850	8	99	100	17:25 18:52					
146.910	4	8	9	16:25 19:12					
146.940	2	96	97	17:25 18:22					
147.090	1	5	5	17:15 17:15					
147.150	1	98	98	16:25 16:25					
147.180	18	6	64	16:59 19:26					

SCAN STATUS

146.415 19:52:47 KEYS: P to print, L/S/W/F/Y save to file

Screen 1 Sweep 64 PgUp/Dn next screen, ESC to quit

Figure 1. YAScan results of a 800 frequency scan from 144 to 148 MHz in 5 kHz increments.

Graph 1 shows a scatter plot of the signal strength of the hits versus frequency. A large proportion of the hits should be disregarded. This is because the passband of the FT736R, nominally 2.7 kHz in sideband mode, allows a signal to be recorded when the transceiver is tuned to a narrow range on either side of the of the true frequency. The false readings are at a lower signal level, however. For most purposes the important observation in each complete eight second sweep is that with the highest S-meter reading. The solid line in Graph 1

connects the respective maximum signal strengths encountered during successive sweeps.

As is evident in Graph 1, Doppler shift caused the received frequency to go from about 435.185 MHz at the beginning KO-23's pass to about 435.165 MHz at the end. The comparatively gradual rise in signal strength at the beginning (occurring at the highest frequencies) was due to a cluster of tall trees in the south which interferes with the low-angle signal path to the antenna. In the middle of the pass, there was a dip in signal strength because my log periodic antenna has a fixed elevation angle of 20 degrees, and does not track the Microsat when it is high in the sky.

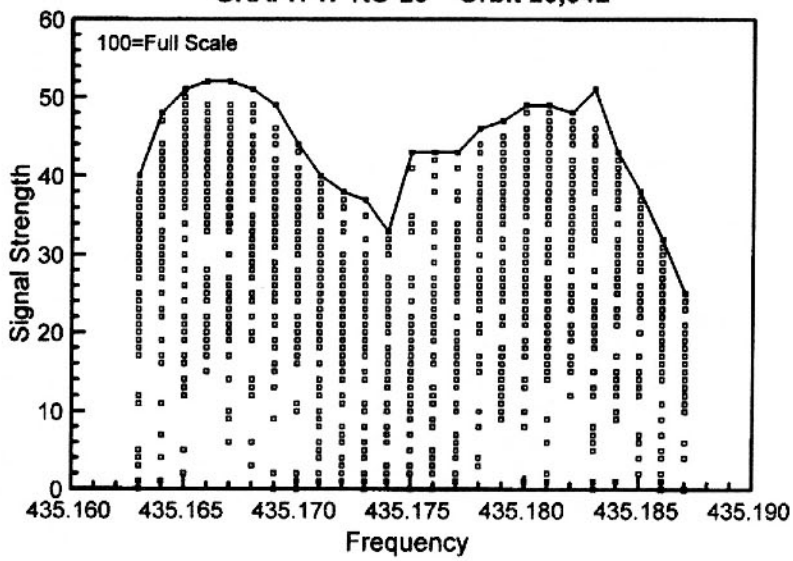
An analogous pattern is reflected in Graph 2 which shows signal strength versus time during the pass. The dip in signal strength at the center of the pass is more pronounced in this portrayal. (In fact, there was a hiatus of 43 seconds when no signal at all was recorded.) Also evident are adjacent smaller dips, likely due to the antenna's sensitivity pattern.

When the S-meter level goes below about 30 (i.e. 30 percent of full scale) the signal is too low for the modem to decode data. In Graph 2, it can be seen that there were drop offs in signal during the middle of the pass causing at least a 10 percent loss of useable signal time. This is the penalty for not having en elevation rotator. There were additional losses at the beginning and end of the pass amounting to another 17 percent, due to factors of terrain.

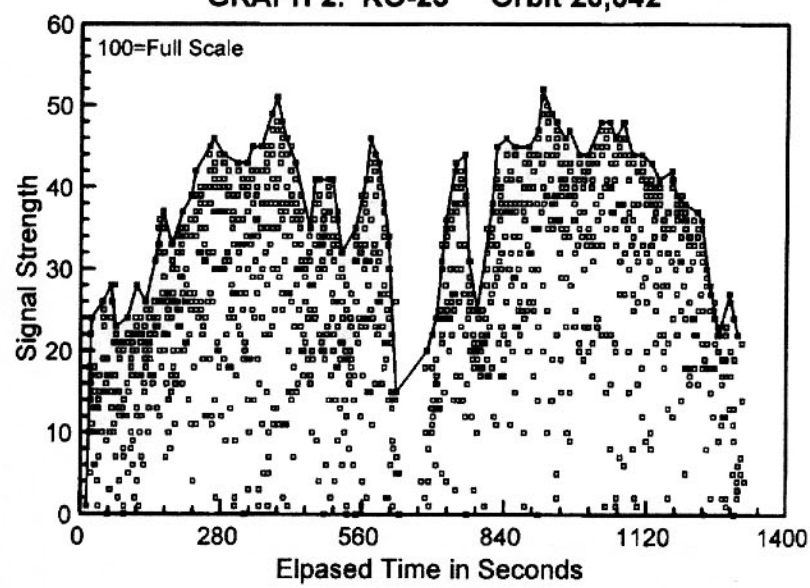
Graph 3 highlights the influence of KO-23's elevation on signal strength. Two plots are shown, a solid line for the maximum-signal scan values during the ascending portion of the pass, and a dashed line for the descending portion. (A scatter diagram of underlying observations is not shown because of the added clutter.) The major dip at the highest elevations is evident as an absence of any signal above 82°. When KO-23 is higher than about 75° the signal drops under the '30' threshold. The discrepancy of the ascending and descending plots above 60°, or so, is in part due to measurement error caused by the fast angular movement of KO-23 in comparison to the 8 second frequency sweep period.

As I hope is demonstrated, using YAscan in conjunction with an FT736R it is possible to collect information that provides insights regarding local congestion in the amateur frequency bands and regarding satellite ground station performance. The scanning capabilities of the FT736R obviously do not match those of a laboratory instrument, and these limitations must be considered when analysing data. A final comment about the capabilities of YAscan. Except for Figure 1, the illustrations in this article were not produced by YAscan per se. YAscan's role was to capture the data which was subsequently manipulated, converted, and translated for analysis and for export to a graphing program. ■

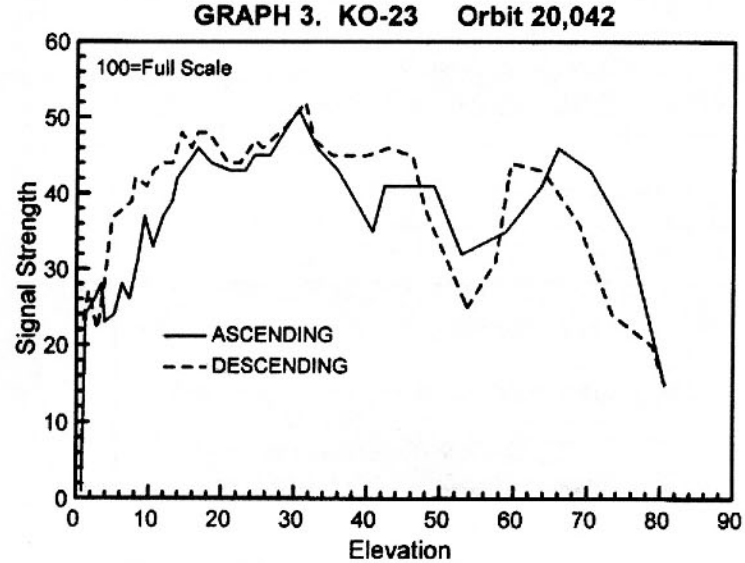
GRAPH 1. KO-23 Orbit 20,042



GRAPH 2. KO-23 Orbit 20,042



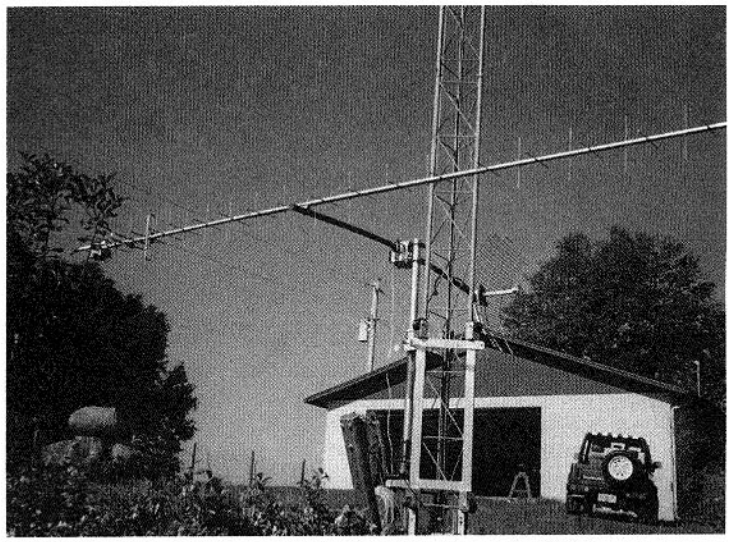
GRAPH 3. KO-23 Orbit 20,042



U-Lift for Satellite Antennas and Rotators

John ,WB4MOX & Beverly WD4MOY Darbyson

We get more than our fair share of lightning strikes as we live in central Florida on top of a 125 foot hill. While we wanted to get on mode-S for quite some time, we knew the chances were high that our converter would get hit by lightning in the first storm. To avoid this situation, we have developed *U-lift* which can be operated by either a hand or electric winch allowing you to either raise or lower your expensive goodies within minutes. Weighing 32 pounds, U-lift is designed for an average tower running from 30 to 70 feet in height. It is constructed of 2x¼ inch 6061-T6 aluminum. U-lift's rubber wheels do not hang up on the tower bolts. We also put guide wire holders to secure to the ground once it is in place. To learn more about U-lift contact WB4MOX or WB4MOY at 6708 CR 651, Bushnell, FL 33513 (telephone: 352-793-4690). ■



The WB4MOX/WB4MOY U-lift operates on rollers allowing antennas to be easily raised and lower on the tower. (WB4MOY photo).

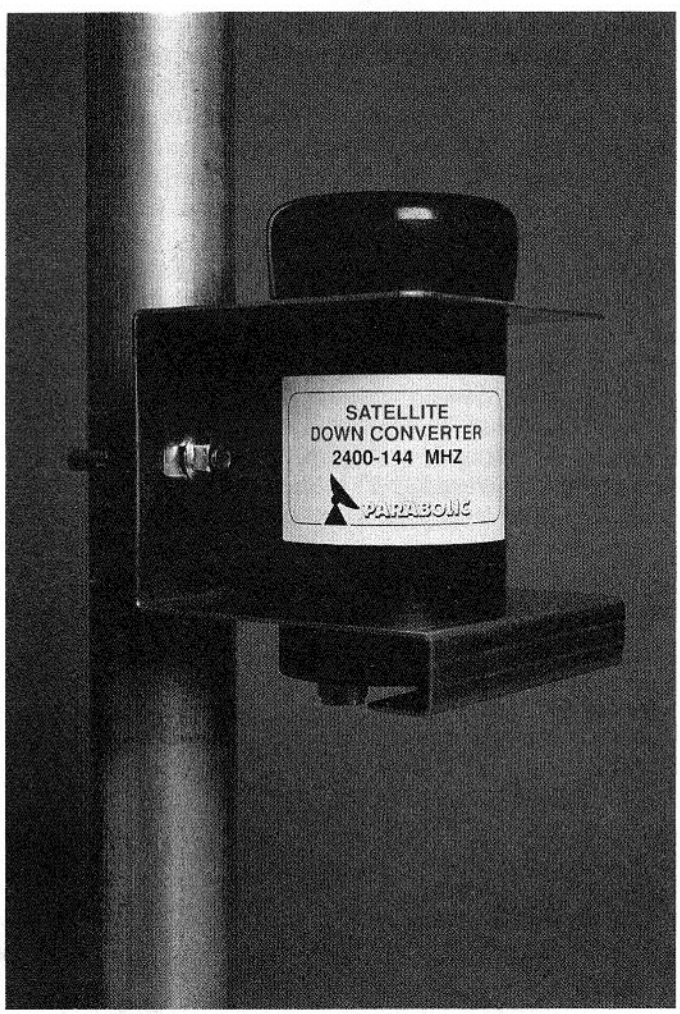
Parabolic AMSAT Mode-S Converter

Parabolic AB has recently announced the availability of a mode-S converter. Designed and manufactured in Sweden using the latest SMB technique, the converter uses an HEMT at the input stage and helix filter for excellent selectivity. The converter is mast mounted and the oscillator has a built-in crystal oven for stability even at low temperatures. DC is supplied through the cable using an optional bias tee and the box is weatherproof.

- Input: 2400-2404 MHz (other frequencies between 2200 and 2450 MHz are available upon request)
- Output: 144-148 MHz
- Noise Figure: Max 1.0 dB (typ 0.8 dB)
- Gain: 30 dB ± 3 dB
- Image Rejection: 35 dB
- Supply Voltage: 11.5 - 15.5 VDC (300 mA)
- Connectors: N-type female
- Size: 75 x 150 mm (excluding mast clamp)
- Mast Clamp: 50 mm supplied (will accept up to 89 mm)

A 2400 MHz helix antenna will also be available as well as a mast-mounted power amplifer for 1268 MHz driven by a 144/1268 MHz up converter.

Suggested retail price is $359 including mast clamp. Bias tee is $33. For further information contact Bengt Jockert, SM6CKU, Box 10257 434 23 Kungsbacka, Sweden (*sm6cku@parabolic.se*). ■



Parabolic Mode-S Converter. (Parabolic AB photo)

Some Interesting WWW Pages

Ashley's Space World: ***http://www.siri.net/~acagle***

Java & Ham Radio:
http://www.images.demon.co.uk/java.html

Field Ops Update: A Look Ahead

Barry A. Baines, WD4ASW, *wd4asw@amsat.org*

Great non-profit organizations have a cadre of dedicated volunteers who can be counted upon to handle the myriad of tasks that must be done. AMSAT is no exception. Field Operations has benefited from the enthusiasm and hard work of many Area Coordinators who have taken the time and effort in their local communities to respond to the variety of requests that are given to them, such as representing AMSAT at hamfests, establishing local nets, serving as Elmers to new satellite users, and educating amateurs on the fun and opportunities for satellite communications.

With the support of our Area Coordinators, AMSAT field operations accomplished a number of goals in 1996:

- As of December 31, there were 164 Area Coordinators in North America, with 75 percent of them having Internet e-mail capability.
- Expanded Field Operations awareness and training via e-mail.
- Developed new resources, such as the AMSAT Resource Listing (given to new members) and Gary Rogers' *Working the Easy Sats* which is distributed on diskette; and
- Provided extensive hamfest AMSAT representation, including the highly successful Dayton Hamvention and the ARRL National Convention in Peoria, IL.

Last year was a year of development, with a new VP-Field Operations and a number of new area coordinators stepping forward to serve as *Ambassadors of AMSAT* in their local communities. Several area coordinators were recognized at the 1996 Annual Symposium for their contributions this year in the areas of resource development (WA4YMZ and WB8CKI), hamfest representation (WA3GOV, KK3K, AA7KC, and VE8EV), and assuming responsibility for representing AMSAT at the ARRL National Convention (W9XA).

What about 1997? Field Operations has set a number of challenging goals that can be achieved with the assistance of AMSAT's membership:

- Expand our field operations presence to fill the *gaps* in our coverage. There are a number of areas where AMSAT does not have a coordinator. For example, there are no Area Coordinators in Idaho, North Dakota, South Dakota, West Virginia, and Wyoming. There are other states that could use additional help.
- Improve AMSAT's hamfest support. There are a number of good hamfests where AMSAT does not have a presence due to lack of volunteers and/or lack of knowledge of hamfests in which AMSAT should participate. We need members to help man the booths and seek out additional memberships.
- Encourage development of new presentation materials for distribution to Area Coordinators and AMSAT members via the web site. Have you developed your own presentations? How about sharing them with other AMSAT members?
- Build greater AMSAT awareness at the local level by creating and participating in AMSAT local nets and making appropriate club presentations. What about already established nets that allow announcements of local interest? Is there an opportunity to provide your local club members with up-to-date information from the AMSAT News Service? We all joined AMSAT presumably because we want to part of a successful organization that is making a difference. Why not share your enthusiasm and knowledge with others?
- Provide Phase 3D Support. Serve as a local distributor of information as the launch date approaches.

As the Phase 3D launch date approaches, I expect that there will be even a greater need for Area Coordinators to represent our organization as interest mounts for this new satellite. We are developing more resources to provide Area Coordinators with information on Phase 3D and how amateurs can access the satellites. Perhaps we can't all be satellite builders, but we can all help develop the user base and increase the enthusiasm for using this new vehicle in space. AMSAT will need to provide the technical information needed for ground stations to be developed by amateurs who probably have never built a satellite station before. Are you in position to keep others informed of Phase 3D developments and advise them of what is needed to work Phase 3D?

The field operations team can certainly benefit from an influx of enthusiastic supporters who are willing to share their knowledge and enthusiasm with their local communities and fellow AMSAT members. If you are interested in helping us meet some of our 1997 goals, please contact me via e-mail (*wd4asw@amsat.org*) or telephone (904-398-5185). ■

NEW SP-2000 & SP-7000 *Heli-Filter SUPER-AMP* PREAMPLIFIERS

Over eight years ago, we introduced our famous **SP-2** and **SP-70** ***SUPER-AMPS***. We are now proud to introduce the **SP-2000** and the **SP-7000** --- a new generation of **SSB Electronic** 2 meter and 70cm mast mounted GaAsFET preamplifiers for Satellite, Weak Signal, Tropo, EME and ATV!

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SP-7000	<0.9	10-20dB	500W	100W

PRICE $249.95

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- Usable DC - >10.0GHz.
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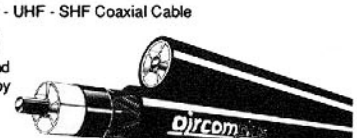

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2400 MHz Receive Converter

Dallas Taylor, VK5WA, ***dallas.taylor@dsto.defence.gov.au***
http://dove.net.au~mark1/EARC/earc.htm

With the launch of Phase 3D imminent there has been a renewed interest in 13 cm activity. The normal intermediate frequency (IF) chosen for 2400 MHz transverters has often been 144 MHz because of the availability of 2-meter transceivers. The use of the 23 and 13 cm bands for the proposed uplink and downlink systems respectively on the spacecraft, means that those of us that rely on transverters must find an alternate IF for either 23 cm or 13 cm, if we are to operate full duplex. One choice is to use either a 50 MHz or 432/435 MHz IF for the 13cm transverter and leave the 2m rig for the 23cm uplink. The use of the 440 to 450 MHz band in some parts of the world may be a better choice for some users, this only requires a trivial crystal change and minor retuning of the local oscillator (LO) board.

In South Australia we have a small group working with FM Amateur Television (ATV) on 2415 and 1250 MHz. Both of these bands requires a down converter that operates with a 480 MHz IF. This current project started as a three way design to:

- down convert from 2415 MHz to 479.5 MHz,
- perform as a transmit and receive converter for weak SSB terrestrial applications between 2400 and 2404 MHz, and
- serve as a satellite receive converter at 2401 MHz.

In Australia the band between 2300-2400 has been effectively lost to the commercial Multipoint / microwave distribution services (MDS/PayTV) since 1993. While we still *share* this allocation, the 100+ Watt services every 7MHz in most capital and regional cities has killed 2304 MHz activity.

A common configuration for satellite down converters has involved the use of simple unbalanced transistorised mixers or alternatively, a singularly balanced 90 or 180 degree hybrid ring with 2 diodes. The main advantage of this arrangement has been the need for only two 50-cent diodes, but at the expense of versatility with the RF LO and therefore IF choices. Generally RF / LO frequency separations of greater than 10 percent create a compromise in the 1/4 wave strip line board lengths in these mixers.

The higher IF of 479.5 MHz for the Frequency Modulated ATV (FMATV) and, 432/435 MHz for SSB made the use of a doubly balanced wideband mixer appealing. The mixer chosen for this is the Mini-Circuits RMS-30. The substrate chosen is the Ultralam 2000 teflon based 31 mil (0.8mm) thick board, and the front end amplifier is the Hewlett Packard (HP) MGA-86576 FET monolithic microwave (small) (MMIC).

Specifications

Receive Converter.

- Input Frequency range:2350 to 2450 MHz
- Noise Figure: >1.8 dB tuned. <2.2 dB untuned
- Gain: 16 dB (typical 18-20 dB) with no IF MMIC .
- 26 dB (typical 30 dB) with MAR-3 MMIC in IF.
- LO drive:-1 to +7 dBm for specified performance.
- LO frequencies/IF frequencies (eg)
  1958MHz/442 MHz,
  1965 MHz/442MHz
  1968MHz/432MHz
  2256MHz/144MHz
  2350MHz/50MHz
  2372MHz/28MHz
- Power supply:12 to 15 Volts@ 25 mA no IF MMIC. @ 60 mA with MAR-3 IF MMIC.

Local Oscillator plus alternate IF's 144, 50, 28 MHz.

Frequency range:1850 to 2050 MHz (alternate 2200 to 2400)

- Output level: +3 dBm (typical +5 dBm).
- Power supply:12 to 15 Volts @ 110 mA.
- Crystal[MHz]:81.87582.000 (alternate IF's 94.000 97.917 98.833) series 5th overtone.

The higher LO frequency ranges can be achieved by cutting the edge coupled lines of the 1950 LO or using one of the pretuned PCB's.

The TOKO coil used in the 2300 MHz is the green 5 turn aluminum core, while the 1950 MHz LO uses a blue 6 turn aluminum core type.

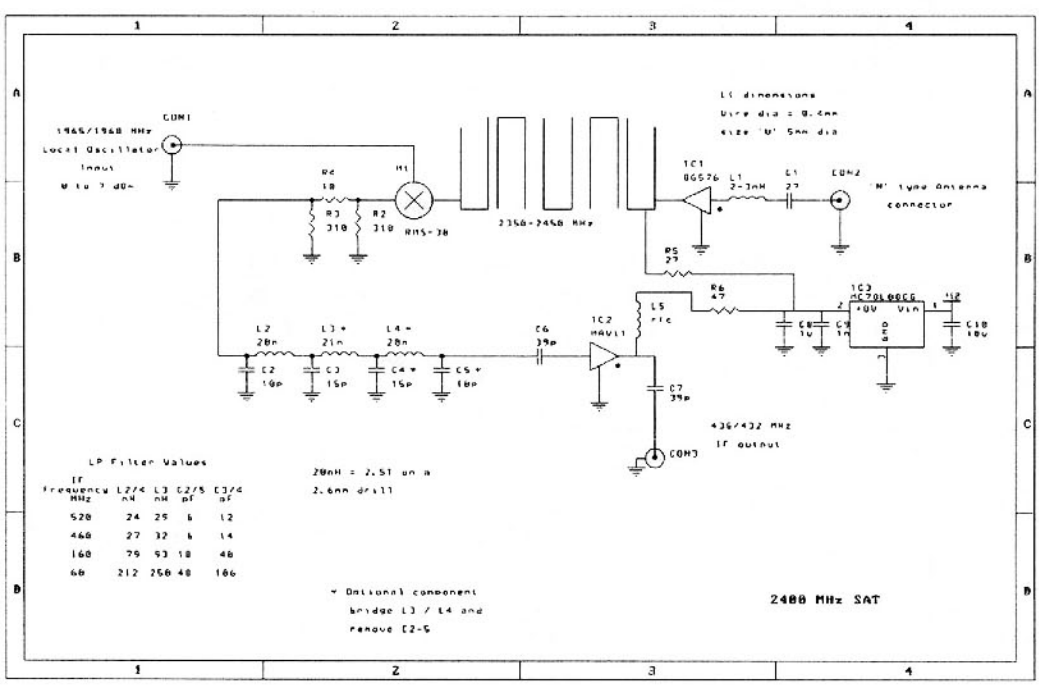


Figure 1. Circuit diagram of the 2400 MHz receive converter.

Receive Converter Design

RF amplifier

The 2400 MHz RF from the antenna (Figure 1) is amplified by a low noise GaAs MMIC from HP, the MGA-86576 X pac device as described by Al Ward in ref(2) and the HP application notes ref(1). This device can achieve a matched noise figure of approximately 1.6 dB with 22 dB gain. The unmatched noise figure is specified as 2.1 dB at 2.5 GHz. To match this device the suggested arrangement is to use a small inductance on the input. The value arrived at in this converter was approximately 4mm of 0.4 mm silver coated wire wrap wire.

The range of operating voltages for the 86576 MMIC are from 5 volts to a maximum of 12 volts with a relatively constant current of 16 mA. The MMIC has an internal self bias circuit that limits internal operation to 5 volts thereby eliminating resistor calculations. The 27 Ohm resistor is described as a de-Q resistance in series with the microstrip line bias decoupling inductance ref(2). The 27 ohm resistor was observed to limit the MMIC performance if voltages fell below about 6 volts.

The voltage regulator chosen for this converter was 8 volts allowing enough margin to bias the IF MAR3 MMIC if used. The regulator also allows the converter to operate over a range of at least 10 to 30 volts for portable and mobile operation.

RF filter

From the RF amplifier the next stage is the image rejection filter (Figure 3 and 5). This filter is a 5 section (4 coupled line) bandpass hairpin microstrip line design, with a total loss of approximately 2.2 dB at the center of the pass band. Figure 2 is a graph of the measured performance of the filter. The filter was designed with the aide of PUFF (ver 1.0). The design has been subsequently checked with CNL/2 software. The main difficulty with PUFF was in the determination of exact microstrip line track widths. The other difficulty with the filter design software package was the determination of the relative dielectric constant that agreed with the modeling of the Ultralam 2000 board material. After a few iterations the relative dielectric constant of 2.4 was chosen, and produced many consistent results. In the case of FR4 board the dielectric constant that worked with software modeling was E_r = 4.4, but the specified value was closer to E_r = 4.8.

This filter is designed to reject image products from the lower sideband of the 1965 MHz LO, i.e. at 1530 MHz by at least 40 dB. This task is rather trivial in this application but with the LO derived from 491.25 MHz, there exists the potential of the 3rd and 5th harmonics of 491.25 MHz at 1473, and 2456 MHz each producing two sidebands. These sidebands at 1038, 1908, 2021 and 2891 have been filtered to greater than -30 dB. The presence of the 3rd and 5th harmonics coming from the LO has also been reduced to low levels in the LO bandpass filtering. This consists of a 2 section 3 line edge coupled 1850-2050 MHz band pass filter. The impact of the mixing from other spurious LO products on the SSB noise figure is therefore reduced to practical levels consistent with the gain and noise figure of the HP MMIC at the front end.

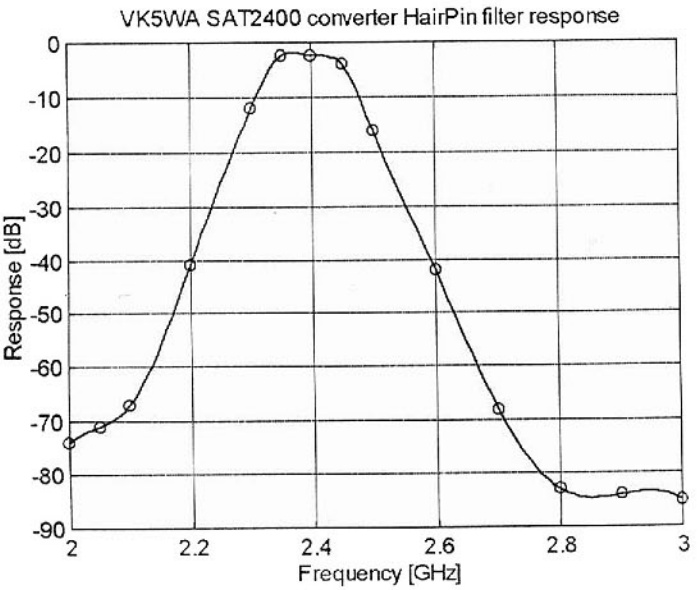


Figure 2. Hair pin filter performance.

Because this converter is designed to operate with an IF frequency as low as 50 MHz, then the image rejection of the LSB at 2300 MHz has been reduced to greater than -10 dB. In later boards I have moved the passband higher to give a roll off closer to -20 dB attenuation at 2300 MHz. If a 28 MHz IF is used, the effective SSB noise figure is reduced by 2 dB to around a total of 4 dB, (due to the LSB folding into the passband) which is still a good performance for satellite working, if you have no other tunable IF frequency available. The use of a *higher performance (NF1.5 dB)* preamp will not appreciably improve the 28 MHz IF noise figure, but will make a useful improvement to the 50, 144 and 435 MHz IF converter versions.

Wideband Mixer

As discussed above the heart of the design consists of a doubly-balanced wideband mixer from Mini-Circuits, the RMS-30. This device is specified for an RF range from 200 MHz to 3GHz with IF's of up to 1 GHz. The conversion gain is about -6 dB with LO-IF and LO-RF port isolation of typically 20 dB. The only way to achieve good balanced performance from any doubly balanced mixer is to terminate the device on all ports over the whole frequency range into 50 ohms. Taking this to a practical level through, a termination on the IF with a 2 dB pad means that the reflected energy out-of-band from the IF filters is reduced by 4 dB. This improvement is a trade off with the extra losses introduced. Use of an invulnerable filter or uniformly terminated diplexer to 'dump' all out-of-band energy into a 50 ohm termination was not considered necessary

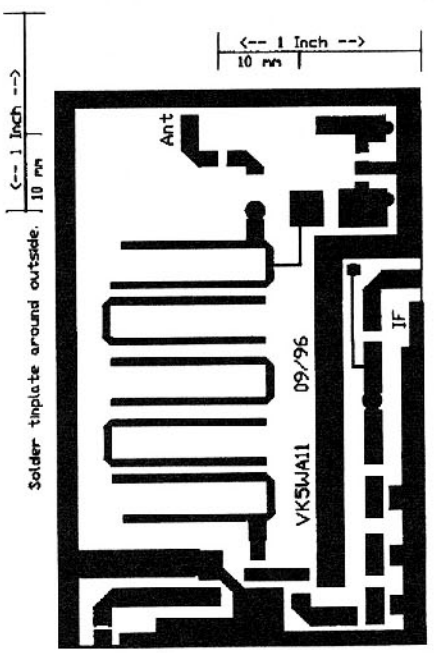


Figure 3. PCB overlay of the 2400 MHz converter.

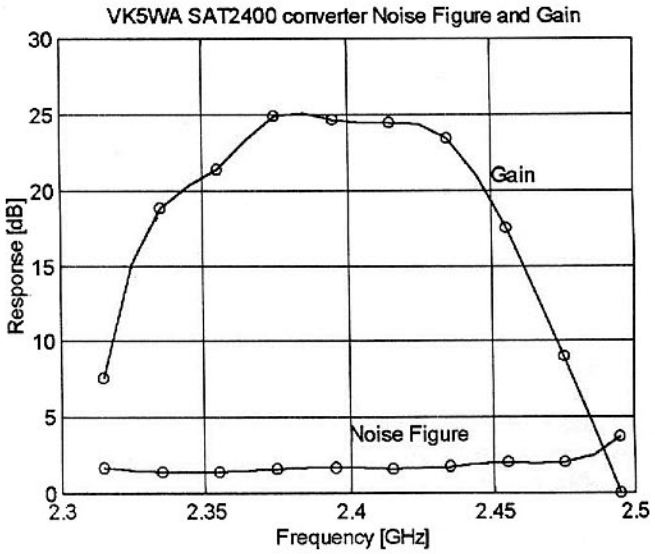


Figure 4. Noise figure and gain of the 2400 MHz converter.

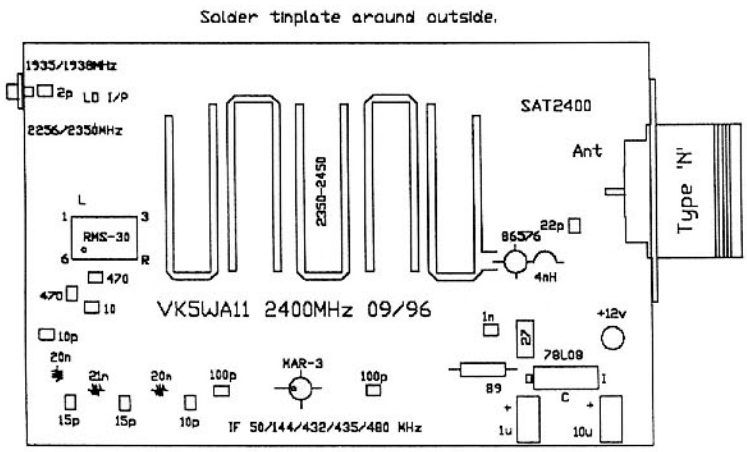


Figure 5. Component overlay of the 2400 MHz converter (track side).

due to the complexity. The LO and RF ports have been left directly connected to the filters. A matching MMIC (eg MAR-1) between the 5 section Hairpin filter and the mixer has not been used due to the high gains already provided by the HP MMIC (measured 24 dB) at the front end.

IF filter and amplifier

The signal from the mixer passes through the 2 dB termination into a 0.1 dB Tchebyscheff (Chebyshev) filter. The PCB has room for a 7 section low pass filter to help with LO rejection when the converter is used for FMATV with the IF at 480 MHz. The need for seven sections in this satellite application is unnecessary with the reasonable filtering provided in commercial SSB 2m and 70 cm equipment, but because of the small losses the 7 sections will not hurt; if you are lazy just use 3 reactive components.

If microwave oven interference is a problem then this filter can be optimized to roll off around 450 MHz. In the case of FMATV at 2415, the capture effect of FM means that the demodulator will find any birdies and spurious signals to lock onto if the received signals are weak. So any extra filtering in that application doesn't go astray at helping with microwave oven QRM, as well as any LO breakthrough. In the case of the 2m IF then the suggested filter values are given in Figure ?, along with a 60 MHz LPF for 6m IF's. There is a position for an extra MMIC after the IF filter. This device could be any number of types. The noise figure here is relatively unimportant, while the gain and 1 dB compression point of the device chosen. If moderate gain is desired (30 dB total) then a MAR-3 ,MAV-11 (11 dB) or MAR-4 (7 dB) would do well. If you really wanted to hammer a deaf IF receiver then throw in an ERA-3 (22 dB) at this point, though it is not recommended (unless you have lots of watery RG58 coax to be coaxed into life with the converter placed at the antenna, and the IF pushed down the coax at 435 MHz).

Construction and tune up of the 2400 MHz Receive converter

The receive converter is deliberately kept simple; in fact if nothing is done except place components, then a very respectable performance can be expected.

There are very few components to be placed on the board. Coupling capacitors are SMD, while the filter capacitors can be SMD or npo miniplate with short leads. The regulator and bias resistors are 1/4 watt. The inductors are wound on a 2.8 - 3mm drill (1/8" drill). Follow the coil details and the low pass filter roll off will be close to predicted. The MMICS are placed in a hole drilled in the board with the legs soldered directly to the ground plane. Alternatively use some thin copper foil on the edges of the hole to allow the MMIC to be placed on the top of the board. The most important thing with the HP MMIC is to have the lowest lead inductance (lead length) to ground; (0.5mm ideal). The RMS-30 mixer

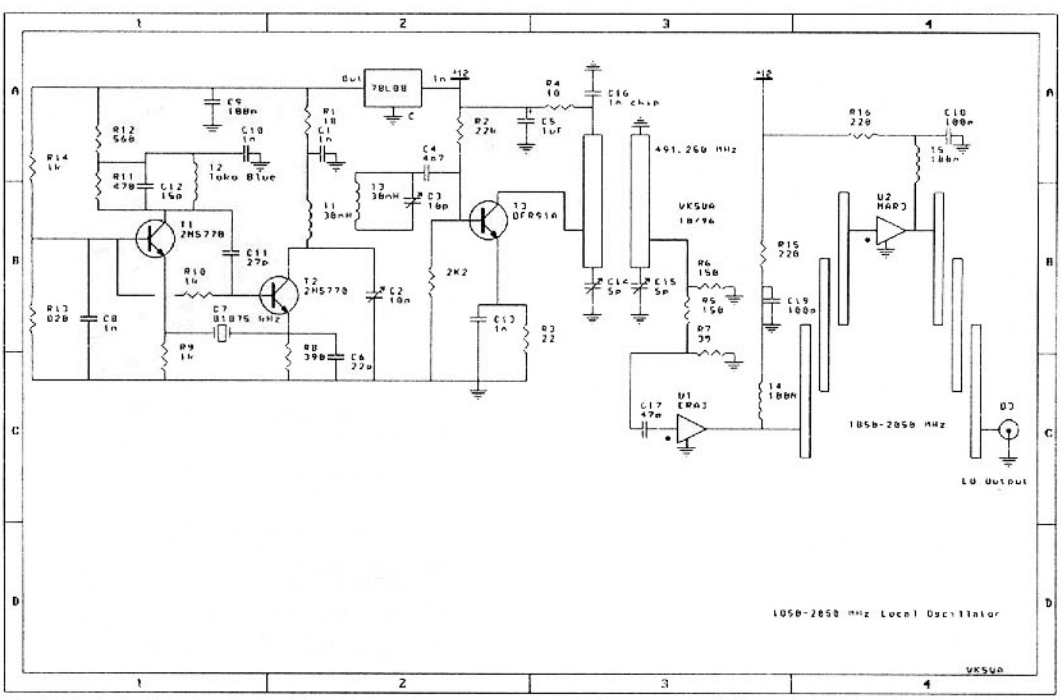


Figure 6. Circuit diagram of the 1965 MHz local oscillator.

has a dot indicating pin 6 which can be confusing.

The antenna connector should be an 'N' type for cost and robustness. Use a sharp knife to cut away a connector profile and solder the ground plane onto the 'N' type at the board edge. Do not mount the board with a gap to the connector, then use hook up wire to find some DC type ground (Figure 5). If you have access then SMA are also very nice, but in reality you then have to adapt to large coax sometime unless the converter is at the feed point. If a preamp is used in front of the converter then a TNC or even a BNC will do (RCA and 259's are definitely out).

Performance

Much of the performance of the various components has been discussed already. The measured Gain and Noise Figure of this converter is shown in Figure 4. The gain and noise figure were measured on an Hewlett Packard 8970B automatic noise figure meter. The plot of the gain is a composite of the image reject filter and the IF filter.

Intermodulation performance has not been measured, but predicted in-band levels suggest - 20 dBm input 3rd order intercept point (IP3) to be realistic. This means that 2 tone RF levels of -57 dBm will produce spurious products at the -130 dBm level. If 2m or 70cm transmitter blocking occurs then a simple input trap could be implemented with a series inductor and trimmer to ground. Suggested values for 70cm are a 20 nH coil and a 3-10 pF trimmer to ground on the input connector. Place the coil against the input connector and the trimmer to ground. Then adjust for maximum effect (smoke). The 20 nH inductor is the same construction as in the 500 MHz Low pass IF filter as indicated in (Figure 1).

Component	*Gain dB*	*NF dB*	*IP31*	*dB Comp*
HP 86576	27	1.7	-3	-17
Hairpin filter	25	1.7	-3	-17
RMS30	20	1.7	-14	-18
2 dB attn	18	1.7	-14	-18
LP filter	17	1.7	-14	-18
MAR-3	29	1.8	-15	-22

Table 1 Cascade analysis of the 2400 MHz receive converter.

To use a common technique that gives one a warm feeling, have a listen to one of the signals transmitted by UO-2 (AO11) on 2401.5 +/- 53 kHz or the DO-17 (DOVE) satellite on 2401.222 MHz +/- 53 kHz.

The DO-17 satellite is very easy to hear on a dipole or quad element (1" sided copper wire square) soldered to the inner and outer of the coax cable tied to the gutter, in the clear. The satellite is easily heard horizon to horizon on CW with up to 10 dB quieting on FM during at least a third of the pass. The only thing to keep in mind is the Doppler of 100 kHz from horizon to horizon.

I have found that the UO-2 satellite to be approximately 10 dB weaker, but still easily heard on CW.

Local Oscillator

The 1965 MHz local oscillator is based on the Sam Jewell G4DDK Butler oscillator design ref(3) with a no tune 4 times multiplier stage (Figure 6). The advantage of using a fixed tuned last stage in the multiplier chain (Figure 8 and 9) is that it simplifies the tune up of the oscillator with a very simple diode detector.

The LO and receive converter are separate boards to allow a check of the LO output before connecting to the converter. Most performance

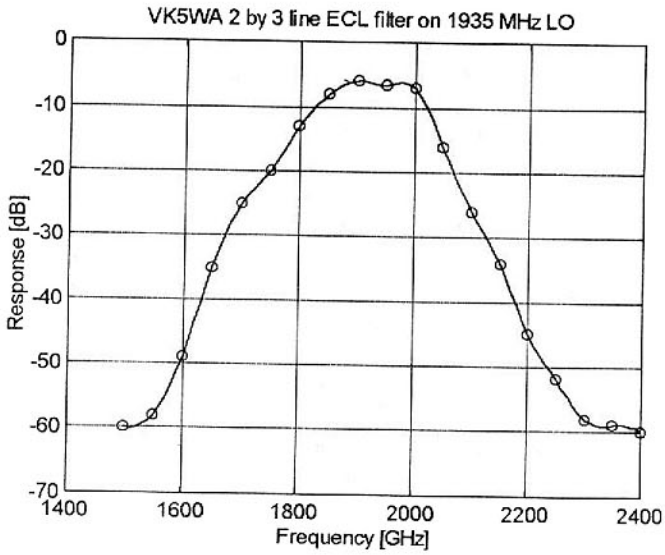


Figure 7. Edge coupled filter response of the 1965 MHz local oscillator.

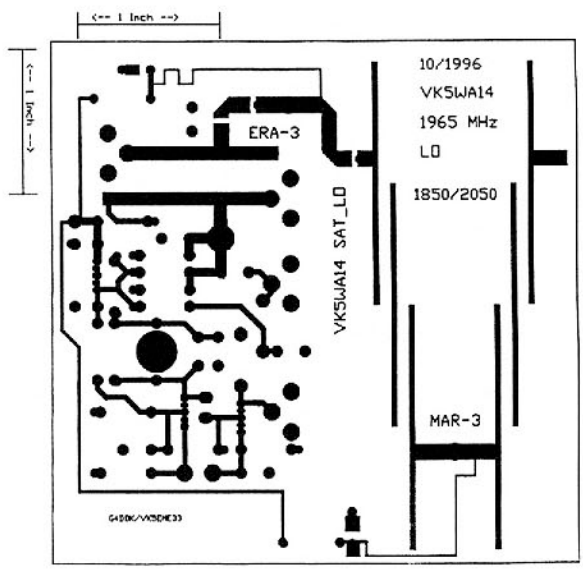


Figure 8. PCB overlay of local oscillator.

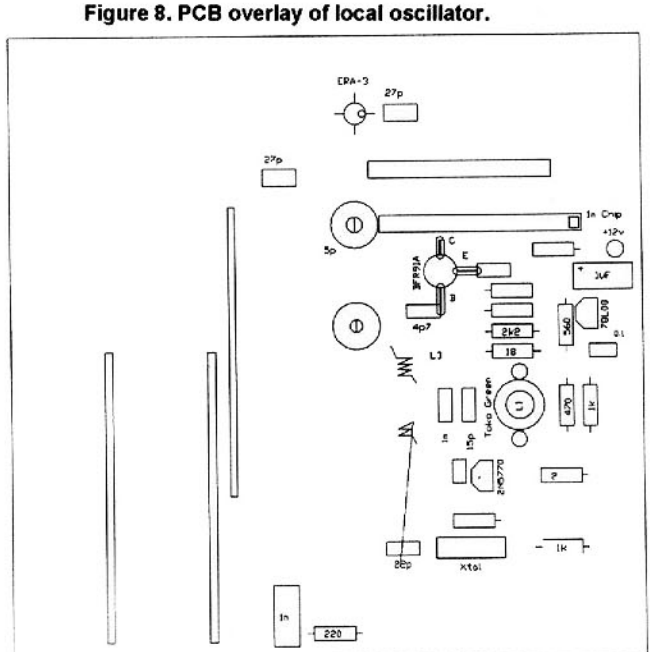


Figure 9. Component overlay of the local oscillator (ground plane side).

degradation occurs via poor LO drive and adjustment, especially where a check of the drive to the mixer is not easily monitored without taking a drill and knife to boards. Another reason for the completely separate LO board is the versatility of changing IF frequencies by a simple changeover of boards; with no changes to the converter board being necessary, especially if a 460 MHz LPF is used after the mixer.

This oscillator has low phase noise, especially important in SSB/CW narrow band microwave working through to 10 GHz and beyond. A series mode 5th overtone crystal on 81.875 or 82.000 (435/432) MHz is multiplied by 3 by the transistor T2 due to the hard limiting of this stage and the tuned circuits consisting of the coupled inductors and the first two trimmer 10 pF capacitors. The transistor T3 doubles the frequency to 491.250 MHz, again tuned by a pair of coupled lines and the two 5pF trimmer capacitors.

The output of this oscillator could be as high as 14 dBm. This level is too high for the ERA-3 MMIC multiplier, therefore a 6 dB pad before the ERA-3 provides a degree of inter-stage buffering and isolation. The ERA-3 produces 2nd, 3rd and 4th order harmonics very efficiently, the first coupled line filter separates the wanted 4th harmonic while attenuating the higher level 3rd before being amplified in the MAR3 MMIC. The second coupled line filter further attenuates the unwanted harmonics of the LO as well as any other inband (2400MHz) noise. The edge coupled filter is almost identical in details to the equivalent hairpin design. The only difference is that straight microstrip lines are involved. This means that there are no corners to model. The use of G10/FR4 board material was chosen for availability, size and cost.

The filter losses were measured to be about 2.5 dB for 2 coupled lines (Figure 7), or about 5 dB total loss. A MAR-3 (or ERA-3 to make sure all is well) MMIC between the stages is used to overcome these losses and to produce approximately +6 dBm total output.

Construction of the LO board is straight forward. The two coils (L2 L3) are 3.5 turns wound on a 3mm form mounted 2.5 mm above the copper ground plane. Use a 51 ohm resistor mounted across the LO output with a 2835 diode in series to monitor the power output. The trimmers (Phillips yellow C2/3 and white C14/15) are ½, 2/3, 2/3 and 3/4 (respectively) meshed for normal operation at 491/1965 MHz output.

Transmit Converter

The receive converter can be configured as a transmit converter by simply reversing the RF pathway. The only switching in this simple design is at one end of the PCB.

The transmitter input to the IF would be attenuated to a level of approximately -5 dBm with SSB peaks of almost 0 dBm. The loss through the attenuator, mixer and hairpin filter will be approximately 10 dB. Therefore with an input saturating at 0 dBm a single ERA-3 MMIC used in the reverse direction in place of the HP86576 will produce a saturating output of approximately 10 dBm. An MGA-86576 MMIC could be reversed and used but at approximately twice the cost of an ERA-3 device. The +10 dBm could then be connected either directly to the antenna, or drive a power amplifier, or even as part of a full transverter, by using a relay (or pin diode switch).

A prototype board has been laid out with the circuit diagram shown in Figure 10. To allow both an MGA-86576 MMIC and a ERA-3 MMIC to be located at the same end of the PCB a PIN diode switching network for the transmit and receive paths has been used. The extra loss through the receiver path via a PIN diode after the MGA-86576 is negligible and will not affect performance. The LO drive arrangement will not change unless the transmitter is required to operate at 2446 MHz where a proposed Phase 3D uplink will be located. In this case a LO could be operating at 2011 MHz for a transmit IF of 435 MHz. The 1965 MHz oscillator described here will not require any modifications except for a crystal change.

The implementation of a full transverter will then require an external IF relay or solid state switch board with a carrier detect circuit. The carrier detect then is used to drive an external relay in the 2400 MHz RF path to allow both the TX and RX to connect to the antenna.

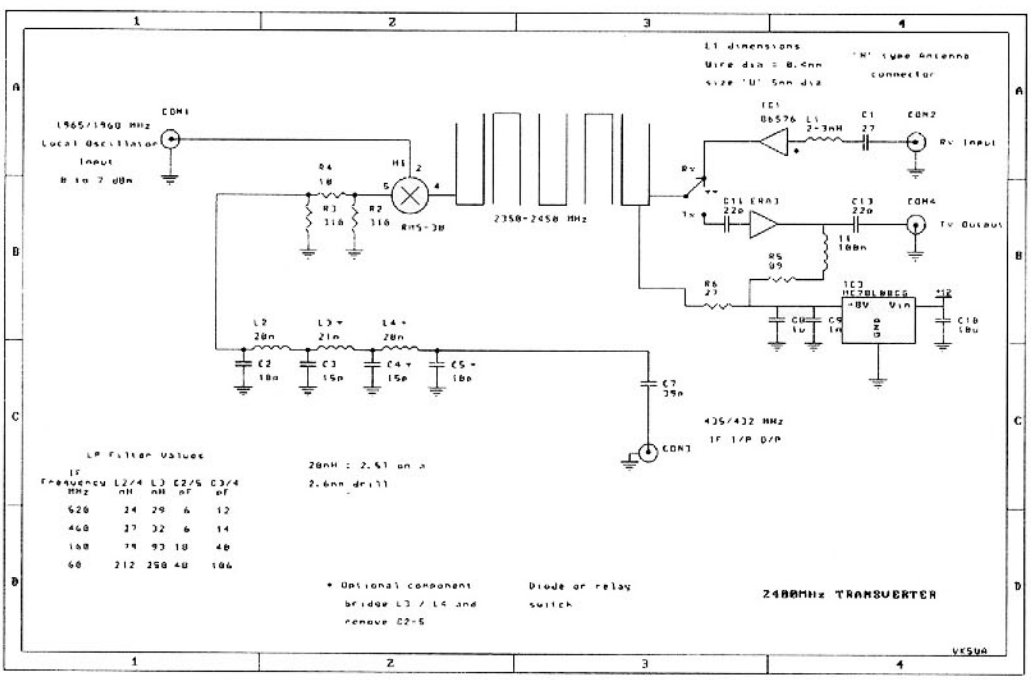


Figure 10. Transceiver design circuit diagram.

References

(1) Hewlett Packard Technical Data; 1.5 - 8 GHz Low Noise GaAs MMIC Amplifier. MGA-86576

(2) Using the MGA-86576 GaAs MMIC in Amateur Microwave Applications; Al Ward WB5LUA

(3) Modern 10GHz Transverter System (Part1). DUBUS 3/1993 C.Suckling, G3WDG & P.Suckling, G4KGC & Sam Jewell, G4DDK. ■

Minutes of the AMSAT Board of Director's Meeting held November 10 and 11, 1996 in Tucson, Arizona

The meeting was convened at 5:03 PM MST on Sunday November 10, 1996 at the Holiday Inn Tucson City Center, Tucson AZ. Members of the Board of Directors (BoD) in attendance were Keith Baker KB1SF, Tom Clark W3IWI, Dick Daniels W4PUI, Bdale Garbee N3EUA, Andy MacAllister WA5ZIB, Bill Tynan W3XO and alternate Board member Joe Holman KA7LDN. Directors Junior deCastro PY2BJO and Bob Myers W1XT were not present.

Other AMSAT-NA officers in attendance were Martha Saragovitz Corporate Secretary, Art Feller W4ART Treasurer, Barry Baines WD4ASW VP for Field Operations, Frank Bauer KA3HDO V.P. for Manned Space Programs, Ray Soifer W2RS V.P. for International Affairs, Russ Tillman KC5JVB AMSAT Journal Editor and Paul Williamson KB5MU V.P. for Electronic Publishing. Also in attendance were Ron Broadbent G3AAJ Hon. Secy. AMSAT-UK, Bill Burden WB1BRE, Chuck Green N0ADI, Doug Howard KG5OA, Harold Reasoner K5SXK, Dan Schultz N8FGV, Paul Shuch N6TX Exec. Dir. SETI League, Steve Smith N8DEZ, Peter Vekinis KC1QF.

Tynan stated, as, had previously been officially announced by Secretary Saragovitz that all of the incumbent Board members had been returned to office by the members voting in the election which closed September 15.

I. 1997 Budget

President Tynan opened the meeting after which Treasurer Feller reported that he had reviewed the Income Section of the 1997 Budget and was in agreement. Tynan said that, following the practice of the past several Board meetings, the expenses for the various departments would be handled as the activities of these departments are taken up. A vote on the budget will be held tomorrow following any adjustments that are needed as a result of decisions made. Dick Daniels reiterated his opinion, voiced at an earlier Board meeting, to the effect that a clearer method of presentation is needed to make the Budget more easily understood. Tynan acknowledged the shortcomings and asked Daniels, and anyone else who felt qualified, to help develop an improved format for this document.

II. Election of Officers

Tynan stated that the officers required by the by-laws are President, Executive Vice President, Secretary, Treasurer, Vice President Operations and Vice President for Engineering. He asked if there were any volunteers for the office of President. There were no volunteers. Tynan indicated a willingness to serve another term if the Board so chooses. The other officers had also indicated a willingness to serve another year. Tom Clark made the motion that the incumbent officers be returned to office. Keith Baker provided a second to the motion which passed unanimously by the Board members present. Tynan said that he would be making appointments of the other various officers who are appointed by the President, and do not require Board action.

III. International and IARU Matters

Ray Soifer announced the reappointment by IARU of Hans van de Groenendaal ZS5AKV as IARU Satellite Adviser and Graham Ratcliff VK5AGR as IARU AMSAT Frequency Coordinator. He also reported that the AMSAT-International e-mail distribution list, which the Board authorized at its November 1994 meeting and charged him with administering, now encompasses AMSAT groups from 25 different countries plus the IARU. Its purpose is to exchange ideas and documents relating to international matters affecting the Amateur Satellite Service among AMSAT organizations and IARU.

The recommendations provided by AMSAT-NA to the IARU's Future of the Amateur Service Committee (FASC) have been included without comment in its First Report. The FASC Report is to be considered at meetings of the various IARU Regions to be held over the next two years, after which the FASC will prepare a Final Report to go the IARU Administrative Council which is charged with making final decisions with respect to the various recommendations. IARU will then use these recommendations in conjunction with its participation in the 1999 World Radio Conference. It was noted that IARU societies in certain nations may be reluctant to endorse AMSAT-NA's suggestion to delete the phrase "*interested in radio technique*" from the definition of the Amateur Service, but it is too early in the process to know how the proposal will fare. It was suggested that the Board continue to work closely with ARRL in pursuing these matters. This will be done.

Feller offered the opinion that it is very important that the concept of what is considered *plain language*, that is anything that is in a publicly available code, be made clear. Soifer noted that this definition seems to have survived in the FASC documents so far. Tynan noted that it is especially important that governments view it this way.

It was mentioned that the next annual IARU International Satellite Forum will be held in conjunction with the 1997 AMSAT-NA Annual Meeting to be held in Toronto, Canada. In the past, this meeting has been held in conjunction with the AMSAT-UK Colloquium, held at the University of Surrey in England each July. Soifer noted that it is IARU's present intention to alternate the site between Europe and North America each year. In response to a suggestion, Tynan will seek a candidate to function as liaison with the Canadian government on matters concerning Amateur Radio satellites in that country. It is anticipated that that person will be made a Vice President of AMSAT-NA.

Soifer said that a document, prepared principally by Graham Ratcliff VK5AGR, which was submitted by Hans van de Groenendaal to IARU and approved by that body, was presented at the 1996 AMSAT-UK Colloquium. This document, entitled *Guidelines for Frequency Coordination Requests in The Amateur Satellite Service* sets forth various criteria needed when the IARU AMSAT Frequency Coordinator is asked for assistance with respect to selecting frequencies for new amateur satellites. Soifer and others have authored a one-page cover document presenting additional information specifically aimed at U.S. groups, that he proposes that AMSAT-NA attach to the IARU document when groups in this country seek our advice relative to new amateur satellite construction projects. After discussion of a number of administrative changes, a motion was offered by Clark, and seconded by Baker, to adopt the proposed cover document. The motion passed unanimously, including those votes received earlier by e-mail. Soifer agreed to handle the suggested administrative changes and send it to President Tynan for signature.

Clark noted that the document that AMSAT-NA had previously drafted, and approved, defining what constitutes an amateur satellite, still provides useful information and is not in conflict with Ratcliff's document. Therefore, he urged that it be sent to U.S. groups seeking information on building amateur satellites, along with the Ratcliff document and the one page cover letter. There was general concurrence that this is a good suggestion, and it will be followed.

Soifer then brought up the draft AMSAT-NA *Guidelines for Satellite Programs Utilizing Amateur Satellite Service Frequencies*. This document had been prepared by a committee appointed by the Board in 1994 consisting of Tynan, Feller, Diersing and Soifer, with Baker ex officio. Several groups which had received draft copies of the document had found it useful. After discussion of subsequent changes, including a change in the name of the document from Guidelines to Background Information, it was moved by Clark and seconded by Baker to adopt the document as revised. The motion passed unanimously. The original drafting committee was charged with completing the final version and submitting it to Tynan for signature.

IV. Educational Activities

Daniels reported on his attendance at the Small Satellite Conference held in September in Utah. He had submitted a paper on Phase 3D but was offered only a poster session (display presented on poster board in the lobby). He noted that educational and commercial interests now dominate the Conference and that AMSAT is not the seat of knowledge that it once was considered to be. He recommended that we attend these meetings in the future, but that we should expect to go to learn rather than teach. He stressed that the kind of people who attend this Conference are the type we should keep in touch with. The thought was expressed that launch opportunities may increase for small satellites and a way should be found to increase the involvement of AMSAT with the small satellite programs of universities and industry.

Clark echoed Daniels comments, mentioning a series of AIAA (American Institute of Aeronautics and Astronautics) meetings held recently at Goddard. There, amateur satellites were barely mentioned and one university participant, with which AMSAT has been heavily involved inferred that they had provided their technical knowledge to AMSAT, when it was definitely the other way around. The conclusion reached was that we must do more to publicize our capability and at the same time form relationships, particularly with university groups wishing to build satellites. One danger pointed out is that many such groups want to use Amateur Radio only as a means of obtaining frequencies for transmitting their data. The consensus was that we must find a way to work with universities to produce new spacecraft for amateur use, but at the same time, not have the amateur bands exploited.

Recent collaborative efforts with builders of educational satellites at the Arizona State University and at the Universidad Nacional Autonoma de Mexico were mentioned as noteworthy examples of AMSAT's involvement with educational

G0MRF S-Band to 70cm Receive Converter Kit Available

A kit of parts for G0MRF project which appeared in the November/December 1996 issue of *The AMSAT Journal* will be available at the end of January or early February 1997. The kit comprises of all the components from the parts list including a 109.333 MHz crystal, and tinplate box from Piper Communications mentioned in the notes. A reprint of the article with additional construction information is also included with the kit.

To further simplify construction, the PCB to be supplied with the kit has been modified to include plated through holes. This will remove the need for the wire feedthroughs used for all earth-grounded connections. The use of a plated through holes printed circuit board will significantly reduce construction time and give a professional finish to the project.

The kit will be available from: *David Bowman, G0MRF, 31 Benson Close, Hounslow, Middlesex England, TW3 3QX*. Cost for the kit is £66.80 (about USD $105.00) and postage in United Kingdom £1.90 British Pounds, Europe £3.75, and United States, VE, Z1, VK £4.75 (about USD $7.50) All non-UK orders will be sent by small packet air mail and include international recorded delivery. Insured post is available to most destinations if required. Please send checks or international money orders in British sterling.

Furthermore, Ron Long, W8GUS provides the following tip for AMSAT members in the USA who might like to purchase kits from Europe, Australia, New Zealand etc. from individuals or small vendors who do not have VISA facilities. Getting a check in a foreign currency from a local bank can be a hassle; and frequently you will find that the exchange rate is not favorable and a large fee is tacked on - as much as $10 - $20 regardless of the amount of the check. Here is a simple way to get a check for a fee of US$3. Call Ruesch International 1-800-424-2923 and request a check for the appropriate Pounds Sterling, NZ$ or whatever domination. When they ask for your account number just say that you would like a temporary account. They will tell you the US$ cost including the $3 fee. You then mail them your personal check for that amount and in a week or so you will receive the check ready to be mailed. Their address is: *Ruesch International, 700 11th St NW, Washington, DC 20001-4507.* ■

institutions. It was proposed that universities be encouraged to look to AMSAT for help in building small satellites and that we should continue to look for worthy university projects while attempting to guard the amateur frequencies from exploitation by those who might try to use them for inappropriate purposes. Clark emphasized that he feels that universities represent an important source of new amateur satellites. He made the point that amateur satellites do not necessarily mean communications satellites. They might be for scientific purposes. Chuck Green gave a brief report on the Arizona State University satellite project. He commented that, in the beginning, they had little knowledge but are learning - much of their knowledge coming from amateur radio people. He said that their science was first class from the start but that they did not have much knowledge, or interest, in the engineering side of satellites. He further noted that initially, their objective in courting the amateur community was to obtain easy frequencies, however, this has changed over the life of the project and that their knowledge of satellite construction has greatly improved. There is no doubt now that theirs is an amateur radio satellite. Tynan noted that AMSAT-NA did send Jan King to one of the ASUSat design reviews and that this, along with the participation of others such as Chuck Green and Lyle Johnson has helped increase the competency of the ASU people.

It was generally agreed that it is important for AMSAT to become more involved with university satellite projects and that it is principally a "marketing" effort to inform them that we do have something to offer them. It was also generally agreed that we have not done much on this in the past few years as we have been concentrating on Phase 4, the Microsats and, more recently, Phase 3D.

Clark noted his belief that the Microsats were an appropriate effort in this direction and they have since been picked up by various university groups as a basic design, appropriate to their level of capability - both in terms of what they can build as well as get launched. He noted that we have lost our momentum on this.

Tynan proposed, as he has at the last several Board meetings, that a department which AMSAT has already set up, known as *Education* and which has not been active in recent years, be revived and tasked with the mission of encouraging links with universities, and promoting educational efforts at all levels. Clark said that he did not believe that such a department should attempt to handle all levels of education and that it would be difficult to find someone to head it, if it has such a broad mission. He strongly recommended that any such initiative be confined to the university level and indicated that he might have a possible candidate in mind if the department's mission is defined this way.

Tynan acknowledged that any job, particularly in a volunteer organization, is accomplished largely in the manner that the person doing it feels most comfortable. He said that perhaps the department in question could be designated *Academic Liaison* rather than *Education* and that it might concentrate its activities on university level efforts. He agreed to discuss the matter further with Clark following the meeting, possibly to identify a potential volunteer to lead this effort.

The subject of educational programs directed toward students at the kindergarten to 12th grade level was also discussed. It was noted that the SAREX activities run under the Manned Space Department fulfill much of this need.

The concept of deriving revenue from educational materials which AMSAT might produce was discussed at some length. Although some disagreed, it was the consensus that, in general, AMSAT should not try to derive funds from this source. The Internet was mentioned as one possible way to distribute such material, without having to print and mail numerous copies. It was acknowledged that major efforts, such as full-length books, could provide revenue, but that this would not be the main intent of the effort.

V. Shuttle Amateur Radio Experiment (SAREX) and International Space Station (ISS) Activities

Frank Bauer reviewed the recently concluded meeting in Houston which involved Amateur Radio representatives from seven ISS International countries (Canada, Germany, Italy Japan, Russia, UK and USA). A French representative could not attend but was brought in via telephone. The meeting laid the groundwork for an understanding among all of the partners involved, so they can work toward a common goal. As such, Bauer concluded that it was a success. Those present at the ISS meeting signed a Letter of Intent attached to a Memorandum of Understanding (MOU) wherein the partners agreed to cooperate in the planning and establishment of an Amateur Radio station on the space station. He noted that each country represented actually consists of two organizations, an AMSAT group and an IARU member society. The intent is to have the MOU signed by duly authorized people from each organization before the end of January. Rosalie White signed for the ARRL and, after reviewing the document, the Board took action directing Tynan to sign for AMSAT-NA.

Tynan mentioned the recommendation made by the German representative attending the meeting, that an international Amateur Radio callsign be sought for the ISS amateur station. He expressed the opinion that this might help solve several problems, including the third party situation and the potential for chaos if each ham on board wants his own station. Also reviewed were some of the equipment architecture ideas advanced. Again, the German representative suggested that the main station be essentially a remote base, with operation accomplished from anywhere on the Station via handheld units.

Also discussed at this meeting were the proposed frequencies for Mir as well as future frequencies for the ISS. In particular, background behind the recent frequency change made by Mir was reviewed. It was noted that the recommendation made at the IARU Region 1 Conference in Tel Aviv of 145.20 and 145.80 MHz for worldwide use by Mir is incompatible with Region 2 (North and South America) usage. Tynan said that he had expressed concern at the Houston meeting that a recommendation coming out of an IARU Region 1 meeting, was immediately implemented for the whole world, without benefit of consultation with the other Regions. In particular, he had noted, that the frequency of 145.20 is in the repeater band, in the U.S. and a number of other Region 2 countries. Bauer recommended adoption of 144.49 MHz for uplinks worldwide and 144.45 or 145.47 MHz for use in Regions 2 and 3.

Bauer reported that, at the Houston ISS meeting, it was proposed that downlink frequencies of 145.990 and 145.815 MHz be considered for future manned space missions. These, it was thought, should have no impact on terrestrial uses in most of the World. While it was recognized that AMSAT- NA, and, presumably other AMSAT groups would probably not be happy that these frequencies lie within the OSCAR band, these specific selections were made in an attempt to a minimize the effect on existing, or planned, amateur satellites. Feller questioned the use of 145.990, noting that it is very close to the edge of the Amateur Satellite Service allocation (144 to 146 MHz) and could cause out-of-band emissions when Doppler is taken into account. Tynan noted that the original suggestion offered at the meeting had been 145.95 and that the exact frequency was modified to 145.990 for that reason. He opined that, if the modulation index is kept below 1.0 (deviation for voice less than 3 kHz), even with Doppler, emissions will remain in-band. Broadbent was asked about efforts in Europe to adopt a 12.5 kHz channel separation. He said that this will probably happen but that most radios are not compatible with it, so that has held it up. It was also noted that the clearing of 145.80 of European repeaters, to make way for satellites, had made 145.20 available for other uses. The use of 600 kHz splits is the norm in Europe as it is here. It has also been reported that there is pressure in Europe to re-allocate repeaters to this 20/80 channel combination, reportedly because satellites are not making use of 145.80. He noted that the AO-13 beacon, which will be going away soon, is on approximately 145.81.

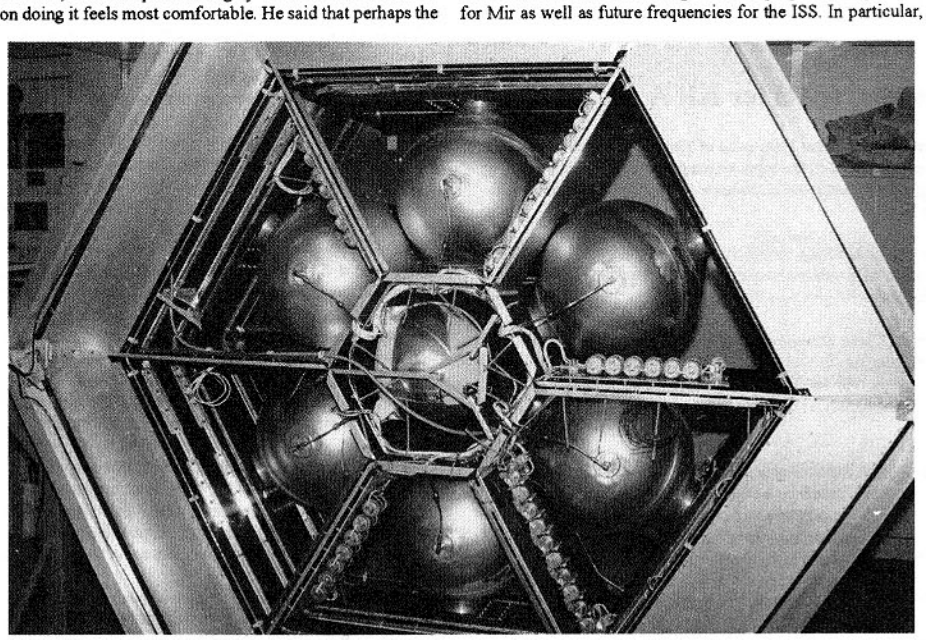
Clark suggested that the 145.815 frequency be modified to 145.8125. He pointed out that this would be in accord with the new 12.5 kHz channel spacing coming into use in Europe and would still not offer a significant problem to the rest of the world, when the adjustments needed to overcome Doppler are considered.

In response to a comment that 145.8125 and 145.990 do not lend themselves to 600 kHz offset, Tynan noted that, while they do not in this country and much of Region 2, they do in Europe and much of the rest of the world.

Clark moved that AMSAT-NA support the use of downlink frequencies of 145.990 and 145.8125 MHz and uplinks of 144.49 (worldwide) and 145.45 or 145.47 in Regions 2 and 3; and that AMSAT-NA go on record as opposing the 145.20/80 combination recommended at the IARU Region 1 meeting in Tel Aviv, since 145.20 is in the Region 2 repeater band. The motion was seconded by Baker and passed unanimously. Broadbent was asked to present these frequency recommendations to Karl Meinzer for consideration by AMSAT-DL. And, Bauer was asked to inform ARRL Technical Relations Manager Paul Rinaldo of the AMSAT-NA position on this matter. Clark registered the opinion, concurred in by all, that the 2-meter band is too small to accommodate all present users.

Bauer mentioned that a NASA official had asked if the school contacts done via SAREX could not use NASA frequencies and equipment, rather than relying upon Amateur Radio involvement. The response given was that using NASA facilities might make the contacts with the astronauts appear "too easy". Currently, there is a lot of student involvement in planning the contacts as well as a cadre of amateurs in the various communities ready to help. If all of these functions were to be taken over by NASA employees, the cost would probably be hundreds of thousands of Dollars per year. This response has apparently put this question to rest.

Bauer announced that one SAREX flight is presently scheduled for 1997 and that 3 to 4 per year are expected to fly. The shortage of "locker space" for astronauts on board the shuttle severely limits what personal items such as ham gear that they may carry aloft.



In this mid-October 1996 photo, the Phase 3D battery mounting and integration effort nears completion at the Phase 3D International Satellite Integration Laboratory in Orlando, Florida. (AMSAT-NA photo by Keith Baker, KB1SF)

VI. SETI League Affiliation

Shuch thanked AMSAT for donating some of the equipment that AMSAT had received from an estate in the Orlando area to the SETI League. He also suggested an affiliation between SETI League and AMSAT and announced that SETI has established a new category of Affiliated Society Membership. He asked that AMSAT officially affiliate with the SETI League with the purpose of exchanging newsletters and sharing certain other resources. It was pointed out that AMSAT already has a category of membership called "Member Society" and that SETI can become an AMSAT member though this class of membership. The yearly dues for Affiliated Society membership in both organizations is $50. Tynan stressed, and Saragovitz agreed, that it is important that checks actually be exchanged to provide a "paper trail" for the transactions. The Board approved this action and it was agreed that each organization will become affiliated with the other in this manner

VII. Phase 3D Financial Report

Baker, as AMSAT-NA's Phase 3D Business Manager, presented a report of Project income and expenses. He emphasized that these figures address only AMSAT-NA's participation and are derived from AMSAT's financial records. He noted that total expenses to October 1, 1996 amounted to $1,274,000. This includes $210,000 provided to AMSAT-DL in connection with the first launch payment. This was derived from ARRL's first fundraising campaign which was targeted to support the launch. Baker estimated that a minimum of an additional $339,000 will be needed to complete and launch the satellite, including $50,000 that has been requested by AMSAT-DL to help defray the final launch payment. He stated that this figure is based on an April 1997 launch. In the event of further launch delays, it will cost AMSAT approximately $12,000 per month to maintain a state of readiness to support the launch. [Since the meeting ESA has announced that the Ariane 502 flight, on which Phase 3D is to ride, has been re-scheduled to early July.] On the income side, Baker said that cash contributions as of October 1st, amounted to $1,380,000 which includes approximately $75,000 received from AMSAT- UK.

Baker continued by noting that current projections suggest that only about $50,000 of additional contributions can be expected. If this amount is realized, it would leave a deficit of approximately $243,000. Thus, he concluded, additional attempts to obtain contributions are vital to the success of the Phase 3D Project.

This prompted a lengthy discussion of fund raising initiatives. Tynan mentioned the "Major Donor" campaign which he has been advocating for some time. It involves the dedication of some piece of spacecraft hardware to those individuals and organizations making substantial contributions. He proposed a minimum of $2,500 for the dedication of a single row of solar cells. Tynan said that he was negotiating with Karl Meinzer as to the details of this campaign. [These Negotiations were successfully completed following the meeting and the campaign is underway. The spaceframe has already been dedicated to ARRL in recognition of its raising approximately $530,000 in its two Phase 3D fundraising efforts.] Tynan further said that each dedication carries with it, the presentation of a large plaque which carries a citation stating the name of the donor and the specific piece of spacecraft hardware dedicated to that donor.

Baker's Phase 3D revenue and expense charts clearly show that the amount we must raise through fundraising, or borrow from our own reserves, is approximately $300,000. The Board members present, plus Saragovitz and Feller, viewed such a prospect with alarm. All expressed serious concerns that such drawing down of reserves would have on the long term viability of the organization. Daniels moved that the President be encouraged to undertake whatever fund raising effort he believes to be appropriate. After a second from Clark, the motion passed unanimously.

VIII. P3D Technical Report

Green reported on progress being made with the RUDAK digital transponder and IHU projects. The RUDAK unit is expected to be completed by the end of 1996. Concern was expressed that schematic diagrams and parts list for the momentum wheel controller had not yet been received from Marburg. [This information has since been received and work was begun to fabricate the flight hardware.] The flight IHU has been completed and is in Germany awaiting application of conformal coating. A prototype is in Orlando for testing with the spacecraft.

Garbee stated that, thanks to help from Frank Bauer, agreements were in place for NASA Goddard to provide two Trimble Tans-Vector receivers, to AMSAT for flight on Phase 3D. Bauer presented the draft of a Memorandum of Understanding (MOU) between AMSAT-NA and the Goddard Space Flight Center and an accompanying Statement of Work (SOW) required for transfer of these receivers. After discussion, Baker moved to accept the document, with a few minor editorial changes which Bauer agreed to make. Daniels seconded the motion which passed with Clark abstaining, to avoid a possible conflict of interest.

Baker said he was happy to see approval of the document, as it may form a model for future agreements of this kind. Tynan echoed that statement saying that if AMSAT-NA is to do anything in the future, besides merely putting out *The AMSAT Journal*, we may have to deal with agreements of this kind. In the course of future projects, he said, it may be necessary, to conclude such agreements with U.S. Government agencies, universities and possibly even foreign governments.

Clark stated that he was happy with the progress being made on the redirected GPS program.

In other GPS related activities, Garbee noted that Bill Hickey has made arrangements for the supply of flight antennas from Ball Brothers. These antennas are currently in Orlando. The design of the preamplifiers was reported as complete, with flight hardware yet to be built. Work on the power control circuitry to permit the Tans-Vectors to be turned on and off by the spacecraft computers is well along. Green provided a prototype during the meeting which Garbee said he would test on his return home.

Garbee said that some questions remain to be resolved concerning testing of the complete system and the software. Other than these items, he foresaw no major technical hurdles before integration testing. Tom Clark made a strong pitch for testing the whole system using the GPS satellites. This would, of course, require that the spacecraft be moved outside of the laboratory. It was stated that such tests are under active consideration.

Daniels reported that the propulsion system is in good shape. The tanks and plumbing are mounted on the spacecraft. The flight PFA is also mounted on the spacecraft and both the arc-jet and liquid fuel motors are in storage in Orlando after having been fit-checked. The LIU board has been completed, and the flight hardware will be constructed shortly. Daniels said that he has plans for an over-all system test of the propulsion system.

IX. Possible Post-Phase 3D Activities

Vekinis presented his concept for the PicoSat Project which was covered in a paper he had given at the Symposium. He said that just prior to coming to Tucson, he had visited Dr. Robert Twiggs at the Small Satellite Development Center at Stanford University. He indicated that they had shown interest in

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participating in the PicoSat Project which features a constellation of small (6" square) satellites in low Earth orbit to provide worldwide amateur communication. He said that, at Stanford, there are as many as 75 students plus one or two post-Ph.D. project leaders who might be available to work on the Project. He said, however, that Stanford does not have the capability needed in RF and he expressed the thought that AMSAT might be interested in participating particularly to fill that need. Vekinis said that the concept calls for PicoSat to operate in the 70 and 23 cm amateur bands and use "off-the-shelf" transmitter and receiver modules. It is to have packet transponder capability and probably employ inter-satellite linking rather than using ground terminals. Several in the room, including several Board members, expressed some healthy skepticism with respect to the proposed approach. In particular, that a satellite as small as that proposed, could accommodate a sufficient source of power, propellant and other hardware to fulfill these goals. Clark suggested that the Project submit a serious proposal and then hold a design review, at which time, knowledgeable people could critique the approaches taken and perhaps offer constructive suggestions. Some concern was expressed that Vekinis is soliciting money for a project that is so far from being shown to be viable. In fact he said that he had raised almost $1,000 at the AMSAT Space Symposium. He was also criticized for inferring that PicoSat is a viable alternative to Phase 3D.

Tynan noted that Cliff Buttschardt has proposed that out-of-service commercial geostationary satellites be made available for use by Amateur Radio operators. Because he was not present, few details were available. It was concluded that this idea requires considerable study before it can be seriously considered and that Buttschardt should be encouraged to develop it further and make a presentation at a future Board meeting. There ensued a discussion on several geostationary concepts which had previously come up. One approach investigated involves putting an amateur package on a commercial satellite. But Clark noted that most commercial satellites are mass limited, and that their owners want to fly as much stationkeeping propellant as possible in order to maximize the satellite's life. Thus, it is difficult to convince those launching commercial satellites to sacrifice life for the mass represented by an amateur package when life means money. The other problem that Clark noted was that, if such an opportunity should come along, it would probably require very rapid response. The idea was investigated a number of years ago, for the amateur community to build a transponder module in advance, that would be ready, when and if, an opportunity to include it in a commercial satellite should present itself. He said that the problem with this approach was that amateurs have difficulty getting fired up to do something as exacting as this, when there is an unknown chance that it might ever be used.

Daniels opined that there may soon be more opportunities forthcoming for the launch of small satellites, but that NASA is not the place to look for such opportunities, as it is no longer in the launch business. Therefore, he felt that AMSAT should develop connections with those U.S. organizations now launching satellites. Baker reiterated his earlier suggestion that AMSAT should continue to explore the possibility of launch opportunities on surplus ICBMs. It was also pointed out that launch opportunities from some other countries such as China, Russia and The Ukraine cannot be ignored. It was noted that David Liberman is probably our best contact with the Russian launch people. It was mentioned that Martin Sweeting at Surrey has been obtaining launches on Ukrainian rockets. Clark repeated the thought that the future of AMSAT depends on small (15 kg) satellites in low (1,000 km) orbits. He emphasized that not only are the spacecraft easier and cheaper to build but have a much greater probability of being launched.

Tynan cited his presentation that appears in the 1996 Proceedings wherein he proposed the construction of three near-geostationary spacecraft using existing technology and a relatively simple design, specifically much that has been developed for Phase 3D, to provide realtime 24 hour per day worldwide communication for amateurs. Several questions were posed as to how various needs of such as satellite would be met, for example how it would kept spinning. Tynan said possibly the same way the Microsats are spun but admitted that what he has presented so far is merely a concept - not a complete design. Daniels acknowledging Tynan's long standing desire to provide the amateur community with 24 hour per day worldwide communications, wondered whether or not this *Great Repeater in the Sky* is the right way to do it. He speculated that it might become so overloaded that no one would want to use it and that maybe the Internet already provides the communications capability being sought. There was a general agreement that the Internet does present a challenge to Amateur Radio in general.

Clark offered the opinion that the Microsats, and other packet satellites, offer the capability that Tynan is seeking - that of providing reliable worldwide communication. Tynan countered that, while they are marvelous, these store and forward satellites do not provide real-time communication which was one of the attributes he is seeking and one which was emphasized in the Proceedings article. Clark questioned whether or not real-time is necessary. Tynan speculated that it may not be necessary, but it is very worthwhile. Clark stressed that he believes that reliability is more important than real-time and said that if you send a message and it takes ten minutes to get there, that's acceptable. Tynan countered that, in the case of Pacsats, it's more like two hours or maybe tonight sometime.

The point was made that, while one opinion seems to hold that it must be small or we can't do it, and the other that we should build big spacecraft that do a lot; maybe we should try to define what we want to do and then try to determine how big the spacecraft needs to be to accomplish the job. Tynan agreed, noting that, if a way can be found to accomplish what he would like to do in a small spacecraft, he would be more than willing to listen. But, he pointed out, one of the problems with small spacecraft is the lack of area for solar cells. He acknowledged that this can be somewhat offset by buying more efficient and expensive cells (gallium arsenide), but the principle holds true nevertheless.

Feller commented on the lack of a role for Amateur Radio satellites in emergency communication. Tynan noted that there had been a few demonstrations of the concept but acknowledged that there been no instances in which amateur satellite played a significant role in emergencies. He did cite circumstances in which they were used to pass some traffic, such as in the aftermath of the recent Hawaiian hurricane. In response to a question as to "what new things can amateur satellites do?"; a discussion followed covering the likelihood of smaller, short-term AMSAT projects stressing reliability of communication over real-time attributes.

Although AMSAT-NA has not been asked to participate, Karl Meinzer's plan for a spacecraft to go to Mars to act as a relay for scientific data (Phase 5), is known to be of interest to several AMSAT-NA members who have been active participants in the Phase 3D Project. Therefore, any plans that we make for follow-on projects, must take into account the possibility that these people may be otherwise occupied. Despite AMSAT-NA's lack of involvement in the Phase 5 Project, several AMSAT-NA members, including Keith Baker and Dick Jansson, did attend the kick-off meeting in Marburg last summer while there on Phase 3D business.

Tynan stressed the point that we must be continuously looking for new people. He cited several who had shown capability on other satellite projects, both in the concept stage and completed spacecraft. In examining what AMSAT-NA might do in the future, Tynan said that one alternative that must be considered, is the possibility of becoming primarily a membership and education oriented organization - publishing *The AMSAT Journal* and distributing tracking software, rather than being an active builder of spacecraft. He emphasized that he was not advocating this approach, in fact he registered his opposition to it; but, he said, it must be included as one of the alternatives. He opined that it would be one way of keeping the organization going for another ten to fifteen years as the membership dwindles. Baker made the point that such an approach is not in accordance with the Bylaws. Dick Daniels voiced the opinion that such a course would represent a hazardous approach to securing our future.

X. Field Operations Report

Baines reported on recent progress made in building up the Field Operations Department in 1996 and his plans for 1997. He said that in the past year, 25 Area Coordinators have provided the major support for hamfests and similar presentations. He also noted that there has been success in recruiting new Area Coordinators through AMSAT-BB and *The AMSAT Journal* and that, as a result, we now have 164 AMSAT Area Coordinators in the U.S. and Canada - 75 percent of whom are on Internet. He also stressed that we are continuously improving the ability of the Area Coordinators to serve their communities. One way this is being done is through the Area Coordinator Newsletter. This goes just to Area Coordinators and is distributed via amsat.org. For new Coordinators, he is stressing the importance of being

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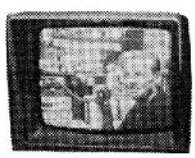

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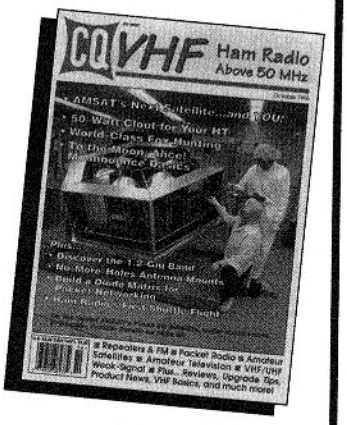

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on Internet so that they can receive the Newsletter as well as communicate with him and the other Coordinators. Baines noted that *in this way, we are developing a team, one that can communicate among itself via the Internet.*

While progress is being made, Baines stressed that there is more to be accomplished. He noted that some parts of the country are still lacking Area Coordinators, or a sufficient number of them to provide the coverage needed. For example, there is a need for additional Coordinators in the Los Angeles area and there are currently none near Kansas City.

New sources of information available now, or soon to be available, include the AMSAT Web site, an informative floppy disk, the Field Ops. Newsletter and a Phase 3D Handbook. Bauer mentioned the set of color slides available for those presenting talks concerning the SAREX program. The archiving and Web Site capabilities developed by Paul Williamson were acknowledged as providing major help to the Field Operations team. Baines also stressed the importance of Satellite Workshops. He said that we had done one of these at the ARRL New England Division Convention in 1995 and had been asked by the League to do on at the Miami Hamfest in early 1997. He said that we now have package presentation material so that a variety of people can deliver such workshops.

Clark complimented Baines for his excellent work. He suggested that the Officers and Directors be added to the list that receives the Field Ops Newsletter. Baines agreed to take care of this.

In response to a question form Tynan, Baines stated that the present level of annual funding for Field Operations of $6,500 is likely to be adequate for the coming year. Saragovitz agreed noting that some of the expenditures are actually carried under Conventions. That amount was retained as the Field Ops. budget total.

XI. Auditor's Report

The audited financial statement for 1995 prepared by the accounting firm of Verkouteren, Auerbach, Olson and Co. was presented by treasurer Feller with the recommendation that it be approved. Clark moved that it be accepted and Baker seconded the motion. It passed unanimously. Clark then moved that the same firm be retained for the coming year. Baker seconded this motion also, which passed unanimously.

XII. Microsat Technology

Tynan noted that several requests for the Microsat data package have been received recently and, in accordance with a previous Board decision, have been referred to Professor Robert Twiggs at Stanford University. Again, in accordance with that previous Board decision, this information is provided without charge to those who Professor Twiggs judges to be worthy. This decision was to be based on his determination that the group intends to construct a spacecraft that can qualify as an *Amateur Radio* satellite. Tynan agreed to obtain, from Twiggs a list of the groups which have received the data package so far.

Clark proposed that the Board pass a resolution recognizing the outstanding efforts of AMSAT-Mexico to implement Microsat technology and to bring Mexico into the space age. They were urged to carry on their valued collaboration with AMSAT-NA in spite of their recent technical problems. Baker made a motion to accept the resolution, it was seconded by Daniels and passed unanimously.

XIII. Executive Session

The Board went into closed (Executive Session) to deal with administrative matters including Martha Saragovitz's performance and compensation review. No record was taken of this portion of the proceedings, except to note that Ms. Saragovitz's services are valued and that she will be granted a modest increase in pay as a result of good performance and a rise in the cost of living.

XIV. *The AMSAT Journal*

Journal Editor Russ Tillman acknowledged the help of Ron Long, Martha Saragovitz, Bill Hook, Andy Reynolds, Buzz Gorsky, and the respective authors in producing each issue of *The AMSAT Journal*. He said that although some mistakes have been made, he has tried to learn and profit from them. He said, that with each issue he and the team are seeking ways to improve the publication. With Long's help, Tillman has attempted to define a role for *The AMSAT Journal* and they have concluded that it should provide a permanent record of what AMSAT does, as well as form the primary source of contact between the organization and its members. In 1997 it is planned to improve the chronicling of events. Tillman questioned whether the Board believes it a good idea to re-publish articles from other AMSAT organizations' publications, for example *OSCAR News*. Tynan expressed the opinion that is a good idea because most AMSAT-NA members do not belong to these overseas organizations and a lot of good material appears in their publications. Specifically, he said, he would like to see more articles translated from *The AMSAT-DL Journal*.

Tillman described his plans for a special Phase 3D issue of *The AMSAT Journal* to mailed within three weeks after the launch. He observed that, in order to accomplish this, he will need to have much of the material ready to go. Clark suggested that a digital still camera be sent with the crew to Kourou so that they could post pictures on the Web page, as well as provide pictures for the special issue. Tynan, who has been trying to collect material for a documentary following the launch, cited the need also for a video camera, probably Video 8 or Hi-8.

Tynan asked Tillman about capital equipment needs for *The AMSAT Journal*. It was concluded that $1000 would be added to the budget to cover the purchase of a scanner and/or a new printer. It was noted that the cost of printing an additional issue (the Phase 3D issue) will add 10% to the Journal budget and Saragovitz pointed out that our postal permit allows the mailing of only 6 issues per year and that each issue must contain less than 15% advertising space. Tynan observed that we have no problem staying under the advertising space limitation, and stated the need for an advertising manager as well as a graphic artist, to handle both ads in our publications as well as ads we submit to other publications. Tynan noted that, for quite a while, he has been handling ads we put in magazines like *QST*, *CQ*,

CQ VHF, Communications Quarterly, 73, Monitoring Times, Space Times and the *Hamvention Program*. He has also prepared a few ads for *The AMSAT Journal*. He admitted that he is not very talented at this, and does not have proper equipment; but there has been no one else to do it.

It was agreed that the Journal operating budget for 1997 will be increased by 10% to cover the cost of the special issue. Tillman stated that he had no need for additional budget increases for other activities, for example - travel. He said that he foresees no other needs beyond those already covered.

Noting the consistent high quality and timeliness of the Journal, Clark proposed a resolution of *extreme commendation* to Tillman and his staff. The Board took such action.

XV. Electronic Publishing and Related Activities

Williamson suggested putting the special Phase 3D issue on the AMSAT Web page. A discussion followed and it was decided that this possibility will be explored.

He noted the increased interest in the AMSAT electronic mailing list. As of the previous evening, the number registered for the various lists was as follows:

- ANS - 1,671
- KEPS - 2,719
- SAREX - 1,410
- AMSAT BB - 1,062

Altogether, he said, there are 4,908 mail aliases. There are 95 megabytes of information available on the FTP site and 35 megabytes on the Web page. The access statistics for the FTP site for month of October, were 19,410 log- in sessions from 7,273 distinct sites, mostly from individuals. The numbers for the Web pages are likely to be even higher, but he has not had the logging turned on. He noted that compliments have been received from users worldwide for the speed and high quality of the AMSAT Web site.

A need for automation is evident because the number of transactions for LISTSERV is becoming overwhelming and they are still being handled manually. Automation will make transactions very fast for those able to follow instructions. The reason for delaying thus far has been that the system may become less user friendly for the inexperienced user and slower for non-routine transactions. No date has been set for implementing this automation.

Clark announced that the registry fee for Internet domains is now $50 per year for their service of listing amsat.org on the Net, and that he had forwarded the bill to the office with a note to pay immediately. Saragovitz assured him that this bill was paid quickly. She suggested, that in the future, arrangements should be made to have this bill sent directly to office.

Williamson reviewed the policies he has been following with regard to electronic services and asked for the Board's concurrence.

- Requests are being granted to those who ask to use the AMSAT logo for linking to our site, provided that this is the specific purpose of the request and that users leave intact the registered trademark symbol.
- Content is restricted to items having some recognizable relation to AMSAT or the amateur satellites.
- Distribution of our mail alias list is permissible. However, the actual Internet addresses are kept private. Noting that the list of callsigns available for aliases is public and published, it was mentioned that one CD ROM publisher has listed amsat.org mail aliases without asking permission.

The Board concurred with the way Williamson is handling these situations.

Concerning the recent increase in callsign changes, Williamson stated that changes in aliases will be made when requested. For the present he is leaving the choice to delete a previously held alias up to the holder.

For purposes of budget planning, Williamson asked the Board to consider funding the purchase of a software tool such as *Adobe Acrobat* to make formatted PDF files. Clark made the point that this type of software would also be of help in the electronic production of our printed Journal. Clark suggested the possibility of asking for volunteers among those who might be capable of writing PDF files.

Tynan asked Williamson to comment on the operating budget allocation for the department. He said that, based on experience, a reduction in the budget for electronic publishing from $5,000 to $2,000 for 1997 would be acceptable. He noted that, thanks to Brian Kantor and others, it has been necessary to spend very little on hardware maintenance and replacement.

Steve Smith offered to purchase an electronic camera for the AMSAT lab for use in photographing the events leading up to and launch of Phase 3D. He was thanked for his offer and a camera suitable for getting pictures quickly onto AMSAT's Web page, and other applications, will be purchased.

Clark, stated, that as a result of Williamson's efforts, AMSAT has been leading the Amateur Radio community in the area of electronic publication and news dissemination. He moved that Williamson be accorded the highest possible commendation for his work in keeping this high-visibility function operating. Baker seconded Clark's motion, which passed unanimously.

Baker announced, that in connection with a Master's program which he is taking, he must complete a project which involves a survey. He has hit on the idea of doing essentially a *customer satisfaction* survey of the users of AMSAT's Internet facilities. As a result, he asked the Board's permission to approve this activity wherein he will use the service itself as a tool for gathering the information. He assured the Board that the privacy of the respondents would be maintained and that responses will be kept anonymous. After a discussion of the techniques to be used for the survey, Daniels moved to support Baker's efforts. Tynan seconded the motion which passed unanimously.

XVI. Budget

Tynan re-stated the anticipated 1997 income figure of $325,300, which he had presented at the beginning of the meeting. Tynan

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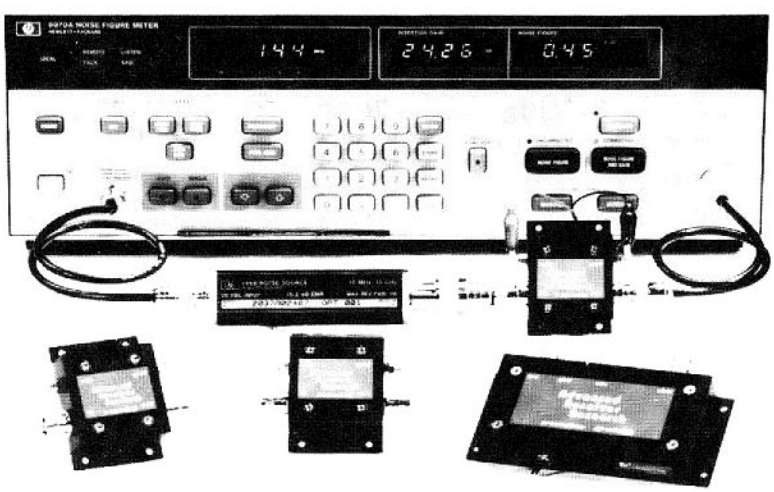

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P28VD	28-30	<1.1	15	0	DGFET	$29.95
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P50VDG	50-54	<0.5	24	+12	GaAsFET	$79.95
P144VD	144-148	<1.5	15	0	DGFET	$29.95
P144VDA	144-148	<1.0	15	0	DGFET	$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	$79.95
P220VD	220-225	<1.8	15	0	DGFET	$29.95
P220VDA	220-225	<1.2	15	0	DGFET	$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	$79.95
P432VD	420-450	<1.8	15	−20	Bipolar	$32.95
P432VDA	420-450	<1.1	17	−20	Bipolar	$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	$79.95
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SP28VD	28-30	<1.2	15	0	DGFET	$59.95
SP50VD	50-54	<1.4	15	0	DGFET	$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	$109.95
SP144VD	144-148	<1.6	15	0	DGFET	$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	$109.95
SP220VD	220-225	<1.9	15	0	DGFET	$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	$109.95
SP432VD	420-450	<1.9	15	−20	Bipolar	$62.95
SP432VDA	420-450	<1.2	17	−20	Bipolar	$79.95
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further said that, following the adjustments made at this meeting, the estimated expenses for 1997 are $650,710. He noted that this leaves a projected deficit of $325,410, most of which is attributable to the Phase 3D spending.

Baker asked for a sense of the Board with respect to how we approach the expected Phase 3D expenditures of approximately $339,000, if fundraising efforts are insufficient to cover this amount. Feller cautioned against dipping into our investments, a significant portion of which is specifically earmarked to support costs associated with serving the Life Members. He cautioned against dipping into this reserve, as it represents funds necessary to insure the continuance of the organization. Clark disagreed, saying that we have a commitment to finish Phase 3D, so we have no choice but to spend whatever money we have, if necessary. He pointed out that this is exactly what we did when we had to recover from the loss of Phase 3A in 1980. The conclusion reached then was that, if we could not produce another satellite to replace Phase 3A, we would probably cease to exist as an organization anyway. So, we did what we had to do, and borrowed from ourselves to build, in company with our German partners, Phase 3B which became AO-10. Daniels concurred, saying that AMSAT should do whatever is necessary to launch Phase 3D. It was generally concluded by the Board members present, that we must have the same kind of commitment in the case of Phase 3D as we did in 1980 following the loss of Phase 3A. Nevertheless, we must keep a close watch on our financial condition. Accordingly Feller was asked to watch the finances and sound the alarm if our investments approach about $300,000. If that point is reached, it was concluded, a special Board meeting will be called to decide a course of action. Tynan expressed the hope that pending fundraising efforts will prevent this situation from occurring. But, all agreed that their success cannot be counted on at this point.

Clark pointed out that we must accurately demonstrate to potential donors that a need exists if we are to have any success in raising additional funds. In other words, *if we aren't broke, they won't feel compelled to give*, he quipped.

Clark mentioned the report submitted by V.P. for Operations Keith Pugh. Activities of his department will again be budgeted at $4,500. After Tynan noted that a few thousand dollars may be added to the budget to cover the expenses of the Department of Academic Liaison, Daniels made the following motion: "Subject to the kids of concerns expressed above by members of the Board and the recognition that we have here a deficit situation that must be dealt with, a motion is made that we approve the budget as presented to us." A second was provided by Clark and the motion passed by unanimous vote.

XVII. Miscellaneous Items

Clark again stated his recommendation that AMSAT become more involved in serving as a focal point for amateurs interested in balloon flight projects. He cited the educational and hardware testing aspects, especially for those at the high school level, noting that such activities may lead to developing an interest in satellite projects. Noting a high level of interest in the subject among amateurs in Colorado, Texas, Iowa and elsewhere, he suggested that Doug Howard, or one of the others active in the balloon field, might serve as a points of contact to provide information to those interested in this subject. The consensus of the Board was that Doug should be asked to investigate this possibility.

The need for a Phase 3D Launch Information Net was mentioned. It was agreed that we should make plans for this. It was also felt that, as prelaunch activity builds, there is a need for more Phase 3D status reports from the Orlando Lab. Baker pointed out that we have an agreement with our European partners, that Phase 3D-related material intended for public distribution that either produces, will be reviewed by the other party before release. The consensus was that items relating to factual accounts of progress, do not require such concurrence - only those matters dealing with policy.

XVIII. *Atta-girls* and *Atta-boys*

The crew that put together the Tucson Annual Meeting were commended. They include:

- Heather Johnson N7DZU and Larry Brown NW7N, Co-Chairpersons
- Darrel Emerson AA7FV, Banquet Speaker
- Dave Medley KI6QE, Prize Chairman
- Dave Burnett WD8KRV Program Chairman
- Martha Saragovitz, who did her usual yeoman service at registration

Thanked also were all of those donating prizes, especially including ICOM America, Inc. and The Amateur Products Group of Kenwood Communications Corp.

Again thanked were Russ Tillman KC5JVB for a superb job with the AMSAT Journal, Paul Williamson KB5MU for maintaining the Electronic Publications Department, Barry Baines WD4ASW for his excellent work in the Field Operations Department. Keith Pugh W5IU was thanked for his Operations Department report and for keeping a steady hand on that department. He was also wished a speedy recovery from recent surgery which prevented his attendance at this year's meeting.

Special thanks and commendation must also go to the entire crew at Orlando, and all of those putting in super effort on Phase 3D. It should be noted that none of the Orlando people have been in attendance at this meeting. They were all too busy putting in long hours on the satellite. Of course our appreciation goes to Martha for her continuing faithful service to the organization. Art Feller thanked the AMSAT Board and officers for their thoughtful support during his illness this year.

XIX. Adjournment

The meeting concluded at approximately 12:00 pm MST on Monday, November 11. Other items, including the budget, are to be handled by e-mail or at a special meeting as the need arises. ■

Satellite Orbital Elements

Ray Hoad, WA5QGD

Satellite	AO-10	AO-27	FO-20	FO-29	RS-10/11	RS-12/13	RS-15
Catalog Number	14129	22825	20480	24278	18129	21089	23439
Epoch Time	96299.11613815	97007.85723758	97007.03266536	97007.18262385	97007.11912897	97008.53102746	97007.18278706
Element Set	463	528	940	49	306	947	189
Inclination	25.8792	98.5643	99.0225	98.563	82.9241	82.9219	64.8167
RA of Node	182.5891	85.5207	359.0892	70.2024	357.7918	37.0616	53.1951
Eccentricity	0.6052907	0.0008961	0.0541305	0.0350572	0.001104	0.0030457	0.0154486
Arg of Perigee	60.2572	357.3108	22.5152	243.4011	316.827	24.1735	162.6777
Mean Anomaly	346.3435	2.7906	339.8762	113.0807	43.1999	336.0845	197.9488
Mean Motion	2.05882271	14.27713272	12.83235406	13.5262836	13.72372994	13.74076143	11.27527418
Decay Rate	-0.00000305	-0.00000117	-0.00000089	-0.00000019	0.00000009	0.00000027	-0.00000039
Epoch Rev	10051	17119	32403	1935	47814	29723	8378
Satellite	UO-11	UO-14	AO-16	DO-17	WO-18	LO-19	UO-22
Catalog Number	14781	20437	20439	20440	20441	20442	21575
Epoch Time	97007.06913666	97007.23206924	97007.18233776	97007.18432153	97007.17857510	97007.15866258	97007.19925715
Element Set	953	238	40	41	44	40	743
Inclination	97.8162	98.5327	98.5483	98.5509	98.5516	98.5544	98.3281
RA of Node	354.9203	92.304	94.8489	95.6059	95.5206	96.0882	73.252
Eccentricity	0.0011458	0.0010944	0.0011078	0.0011746	0.0012211	0.0012539	0.0008452
Arg of Perigee	152.841	326.2681	327.843	326.252	327.1608	327.4868	19.122
Mean Anomaly	207.3397	33.7799	32.2071	33.7921	32.8813	32.5542	341.0283
Mean Motion	14.69513741	14.29945002	14.29995808	14.30137027	14.30106343	14.30217949	14.37051971
Decay Rate	0.0000003	0.00000004	0.00000049	-0.00000017	0.0000003	-0.00000023	0.0000002
Epoch Rev	68759	36321	36322	36325	36325	36327	28736
Satellite	KO-23	IO-26	KO-25	POSAT	Mir	Hubble	Phase 3D 502 est
Catalog Number	22077	22826	22828	22829	16609	20580	99934
Epoch Time	97007.42390446	97008.25840935	97007.77047602	97007.22926925	97009.51130032	97009.34239906	96.26025523
Element Set	632	526	506	520	948	909	3
Inclination	66.0773	98.5646	98.5601	98.5621	51.6505	28.4705	60.0203
RA of Node	121.835	86.1213	85.7143	85.2605	163.764	333.2925	342.7876
Eccentricity	0.0014838	0.0010297	0.0010985	0.0010446	0.0008656	0.0006412	0.6752895
Arg of Perigee	250.6372	356.0149	341.3616	343.6092	252.0358	170.4457	180.1221
Mean Anomaly	109.3042	4.0945	18.716	16.4748	108.0348	189.6251	179.5089
Mean Motion	12.86300303	14.27823228	14.28164739	14.28146984	15.60214184	14.91154567	1.51063968
Decay Rate	-0.00000037	-0.00000025	-0.00000008	0.00000015	0	0.0000033	0.0002
Epoch Rev	20707	17126	13931	17115	62225	16938	2

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